

THE INFLUENCE OF PLASMA PRETREATMENT ON THE STRUCTURE AND ANTIMICROBIAL PROPERTIES OF KNITTED FABRICS TREATED WITH HERBAL EXTRACTS

Dragana Grujić¹; Aleksandar Savić¹; Ljiljana Topalić-Trivunović¹; Simona Jevšnik²;
Tatjana Rijavec³; Marija Gorjanc³

¹University of Banja Luka, Faculty of Technology, Vojvode Stepe Stepanovića 73,
78000 Banja Luka, Bosnia and Herzegovina

²Istanbul Technical University, Textile Technologies and Design Faculty, İnönü Caddesi,
No: 65, Gümüşsuyu (34437) Beyoğlu, İstanbul, Turkey

³University of Ljubljana, Faculty of natural sciences and engineering, Snežniška 5,
1000 Ljubljana, Slovenia
e-mail: dragana.grujic@unibl.rs

Abstract

In this paper we examined the effect of plasma pretreatment on the structure and antimicrobial properties of knitted fabrics (100% cotton, 100% bamboo and 50% cotton/50% bamboo) treated with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. The influence of water vapour plasma pretreatment on the surface functionalization or change of the structure of the knitted fabrics is evaluated with SEM. Antimicrobial properties of knitted fabrics treated with herbal extracts were tested on *Escherichia coli*, *Staphylococcus aureus* and *Candida albicans* by using the parallel streaking method (AATCC TM 147-2004). The degree of coloration was evaluated with CIELAB method and with stereomicroscope. It was found that the plasma pretreatment and processing with the herbal extract of *Reynoutria japonica* Houtt. had a positive impact on the antimicrobial activity of the knitted fabrics against *Staphylococcus aureus*.

Introduction

Fabrics dyed with extracts from herbal plants are favoured by sensitive people in the fight against various kinds of allergies caused by synthetic colours. This dyeing process is an ecologically clean technology and plant extracts used for this process are obtained from natural renewable resources [1, 2]. Using scientific and engineering knowledge in the field of surface treatment of materials enables the development of new textile materials with advanced properties, i.e. with additional functionality [3]. The surface textile treatment by low temperature plasma technology is more and more popular as a surface modification technique [4, 5]. Textile materials subjected to the plasma treatment undergo chemical and physical transformations associated with chemical changes in the surface layer, structural changes of the surface layer, and the changes in the physical properties of the surface layer. Plasma treatment of fibre and polymer surfaces results in the formation of new functional groups, such as -OH, -C=O, -COOH, which affect fabric wettability as well as facilitate graft polymerisation which, in turn, affects liquid repellence of treated textiles and nonwovens [5]. This process offers numerous advantages over the conventional chemical processes (drastic reduction in pollutants and a corresponding cost reduction for effluent treatment) so it can be considered as an environmentally benign technology [4, 6]. The low temperature plasma is a partially ionized gas with electron temperatures much higher than ion temperatures. The high-energy electrons and low-energy molecular species can initiate reactions in the plasma volume without excessive heat and substrate degradation. Low temperature plasma can be

applied to textile processing because most textile materials are heat sensitive polymers. With this method, a large variety of chemically active functional groups can be incorporated into the textile surface. The results of this activity can be the improvement of wettability, adhesion of coatings, printability, induced hydro- and/or oleophobic properties, changing physical and/or electrical properties, cleaning or disinfection of fibre surfaces, etc. [7, 8]. For the textile dyeing we commonly used dye solutions that provide a good degree of coloration, antimicrobial and deodorizing properties, UV protection, etc. The colour of herbal extracts and their antimicrobial effect come from substances with a different chemical composition (anthocyanins, anthraquinones, flavonoids, etc.) [9, 10].

1 Research Subject

Due to the fact that the bioactive substances from plants may slow or prevent the growth of microorganisms, there is a growing interest to study their application in textile processing [11-15]. However, the effect of water vapour plasma pretreatment on the structure and antimicrobial properties of knitted fabrics treated with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. is not sufficiently explained in the literature. Hence, the aim of this paper is to present the benefits that came with the surface activation of knitted fabrics with water vapour plasma in a better absorption of alcoholic herbal extracts of *Achillea millefolium* and *Reynoutria japonica*, which could increase the antimicrobial activity of these fabrics.

2 Materials and Methods

Three different kinds of fabrics were used with the same constructional characteristics and roughly with the same surface mass. They were made from two kinds of yarn, whose main characteristics are given in Tab. 1. The basic characteristics of the knitted fabrics are given in Tab. 2, and the research model is in Fig. 1.

Tab. 1: Basic characteristics of the used yarn

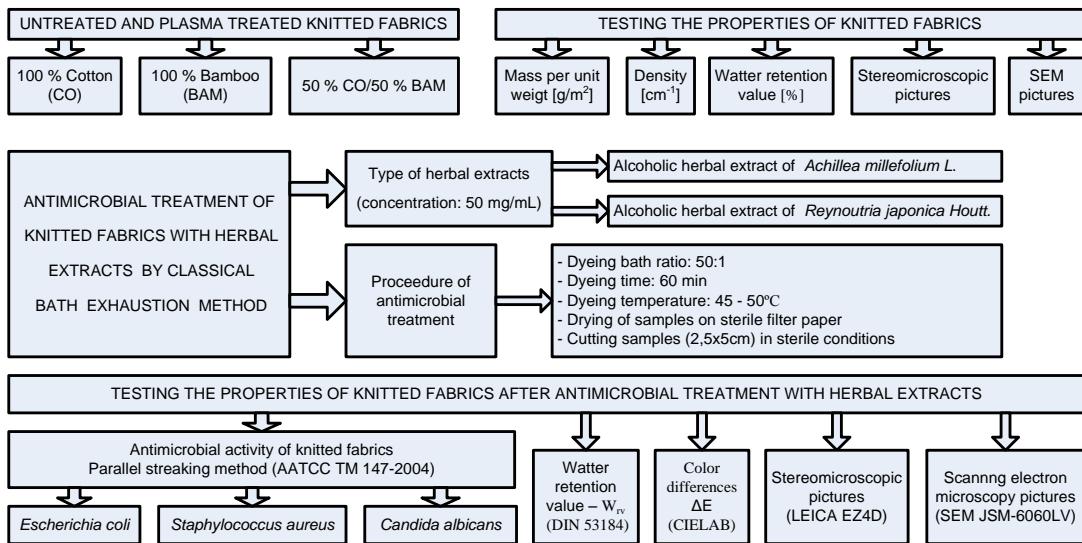
Type of yarn	Mass per length [tex]	Breaking strength [cN]	Elongation at break [%]	Twisting [m ⁻¹]
PAMUK	28.86	148.2	2.71	642.8
BAMBUS	30.16	174.5	7.59	206.8

Source: Own

Tab. 2: Basic characteristics of the knitted fabrics

Code of fabrics	Type of weaves	Mass per unit weight [g/m ²]	Density [cm ⁻³]		Raw material composition
			Gv	Gh	
CO	Singl	111.89	17	17	100 % cotton
BAM	Singl	117.60	17	17	100 % bamboo
CO/BAM	Singl	109.15	17	17	50 % cotton, 50 % bamboo

Source: Own



Source: Own

Fig. 1: Research model

The research model is shown in Figure 1, including the information on the tested knitted fabrics which were treated with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. (extracts concentrations – 50 mg / mL) by the classical bath exhaustion method. Sorption properties of the knitted fabrics were determined by measuring the water retention value, before and after processing them with herbal extracts. The degree of coloration of differently processed knitted fabrics was evaluated on the basis of stereomicroscopic pictures and the CIELAB method. The influence of water vapour plasma pretreatment on the surface functionalization or change of the structure of the knitted fabrics was evaluated with SEM. Antimicrobial properties of the knitted fabrics treated with herbal extracts were tested on *Escherichia coli*, *Staphylococcus aureus* and *Candida albicans* by using the parallel streaking method.

2.1 Sorption properties of the knitted fabrics

The water retention value of the raw and water vapour plasma treated knitted fabrics, as a parameter of sorption properties, was determined before and after the treatment with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. Determination of the water retention value in the knitted fabrics WRV (%) by the centrifugation method was performed according to the standard DIN 53 814 [16]. Water retention value in the knitted fabrics WRV (%) was calculated according to formula (1):

$$W_{rv} = \frac{m_c - m_{kl}}{m_{kl}} \cdot 100 \quad (1)$$

where:

m_c is the mass of the centrifugated sample [g],

m_{kl} is the mass of the conditioned sample [g].

2.2 Stereomicroscopic pictures and spectrophotometric analysis of samples

To notice the changes in the surface structure and the degree of coloration of differently processed knitted fabrics treated with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. the device LEICA EZ4D was used on 30X zoom to make stereomicroscopic recordings.

The degree of coloration of the knitted fabrics was analyzed with the spectrophotometer CM-2600d / 2500d before and after water vapour plasma treatment, before and after processing with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. On the basis of the measured parameters CIE $L^* a^* b^*$, the value of difference in color was determined by equation (2):

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}, \quad (2)$$

where L^* is chrominance and a^* and b^* are coordinates.

On the basis of the results obtained for ΔE it was determined what difference of color reproduction can be observed when comparing the knitted fabrics treated with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. to the initial sample (untreated knitted fabrics and knitted fabrics treated with water vapour plasma).

2.3 Investigation of antimicrobial activity

Antimicrobial activity of alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. with respect to *Escherichia coli* and *Staphylococcus aureus* as well as yeast *Candida albicans*, was tested by the parallel streaking method (AATCC TM 147) [17].

The concentration of bacteria and yeast was 0.5 McFarland standard.

After incubation, zones of inhibition were measured from equation (3):

$$Zi = (T - D) / 2 \text{ (mm)} \quad (3)$$

where:

Zi - width of zone of inhibition,

T - width of sample + zone of inhibition,

D - width of sample (mm).

If there is no zone of inhibition, and no growth below the sample, then it is defined as contact inhibition.

3 Results and discussion

Water retention values (W_{rv}) and stereomicroscopic pictures of untreated, plasma pretreated knitted fabrics and knitted fabrics treated with alcoholic herbal extracts are given in Tables 3 and 4.

Tab. 3: Water retention value – W_{rv} (%)

Treatment of knitted fabrics	Type of knitted fabrics		
	CO	BAM	CO/ BAM
Without pretreating (untreated)	34.89	70.20	55.84
Pretreated with plasma of water vapour (plasma)	34.86	71.60	52.97
Untreated + extract <i>Achillea millefolium</i>	28.50	63.81	43.83
Plasma pretreated + extract <i>Achillea millefolium</i>	22.34	48.93	39.07

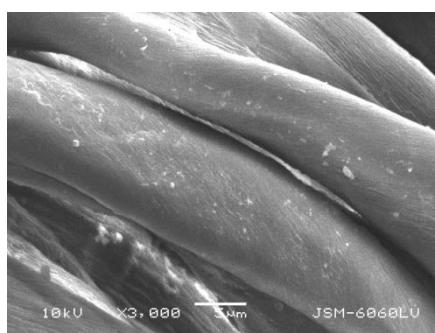
Source: Own

Tab. 4: Stereomicroscopic pictures of untreated, plasma pretreated knitted fabrics and those treated with alcoholic extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt.

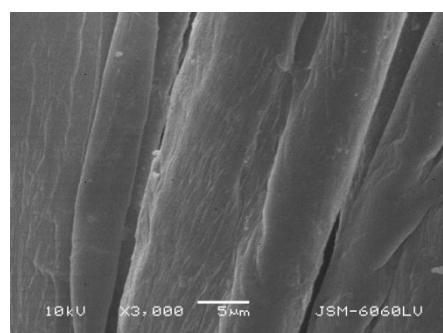
Type of knitted fabrics	Type of treatment					
	Untreated	Pretreated with plasma	Untreated + alcoholic extracts of <i>Achillea millefolium</i>	Plasma + alcoholic extracts of <i>Achillea millefolium</i>	Untreated + alcoholic extracts of <i>Reynoutria japonica</i>	Plasma + alcoholic extracts of <i>Reynoutria japonica</i>
CO						
BAM						
CO/BAM						

Source: Own

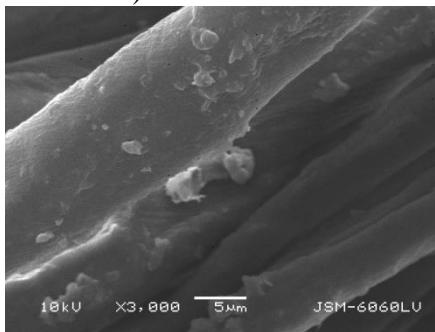
Scanning electron microscopy pictures of untreated, plasma pretreated and knitted fabrics treated with alcoholic herbal extracts of *Achillea millefolium* are shown in Figures 2-4.



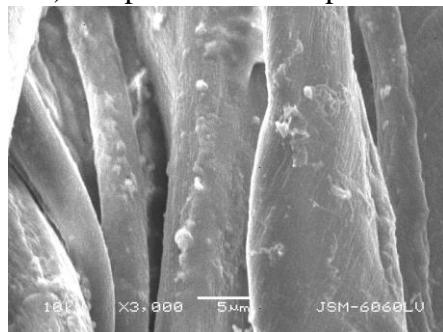
a) Untreated CO



b) CO pretreated with plasma



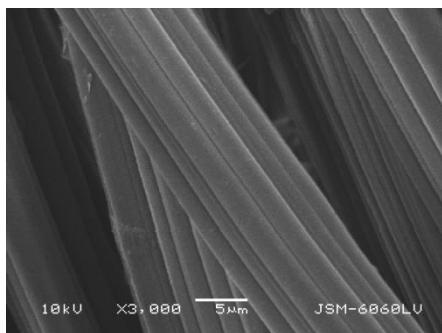
c) Untreated CO + alcoholic extract



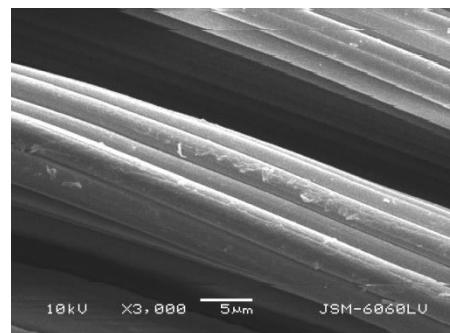
d) CO pretreated with plasma + alcoholic extract

Source: Own

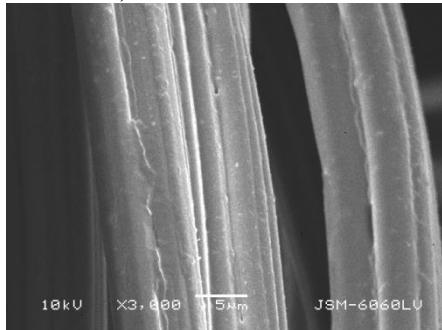
Fig. 2: SEM pictures of CO untreated, plasma pretreated and treated with alcoholic herbal extracts of *Achillea millefolium* L.



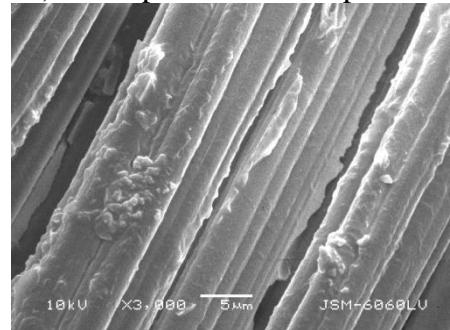
a) Untreated BAM



b) BAM pretreated with plasma



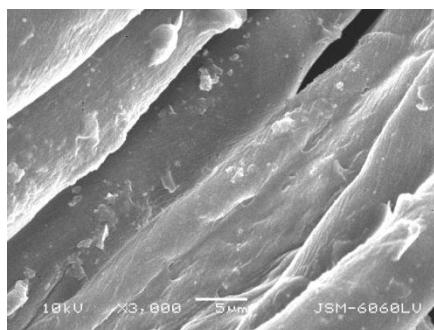
c) Untreated BAM + alcoholic extract



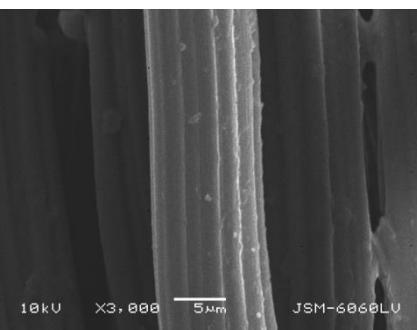
d) BAM pretreated with plasma + alcoholic extract

Source: Own

Fig. 3: SEM pictures of BAM untreated, plasma pretreated and treated with alcoholic herbal extracts of *Achillea millefolium L.*



a) Untreated CO/BAM + alcoholic extract



b) CO/BAM pretreated with plasma + alcoholic extract

Source: Own

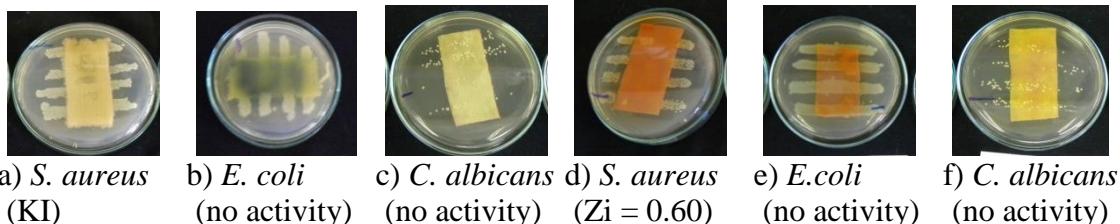
Fig. 4: SEM pictures of CO/BAM untreated and plasma pretreated + alcoholic extracts of *Achillea millefolium L.*

Tab. 5: Antimicrobial treatments of knitted fabrics with alcoholic herbal extracts

Treatment		CO		BAM		CO/BAM	
		untreated	plasma	untreated	plasma	untreated	plasma
<i>Achillea millefolium</i>	<i>Staphylococcus aureus</i>	KI	KI	Zi=3.44	Zi=1.50	KI	KI
	<i>Escherichia coli</i>	NA	NA	NA	NA	NA	KI
	<i>Candida albicans</i>	NA	NA	NA	NA	NA	NA
<i>Reynoutria japonica</i>	<i>Staphylococcus aureus</i>	Zi=0.32	Zi=0.6	Zi=0.65	Zi=0.72	Zi=0.50	KI
	<i>Escherichia coli</i>	NA	NA	NA	NA	NA	NA
	<i>Candida albicans</i>	NA	NA	NA	NA	NA	NA

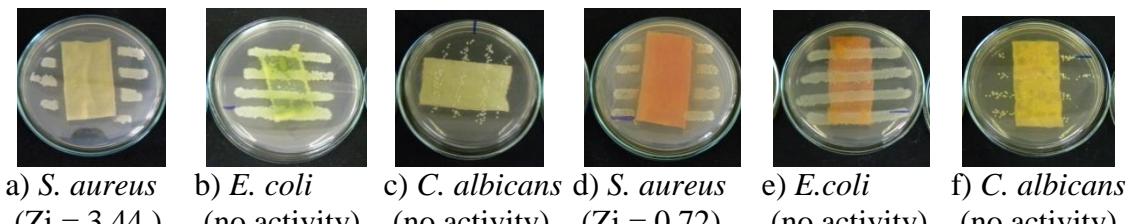
NA – no activity; KI – contact inhibition; Zi – inhibition zone in mm

Source: Own



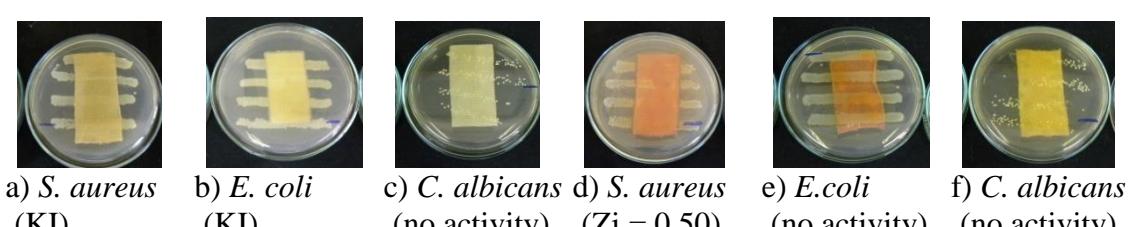
Source: Own

Fig. 5: Antimicrobial treatments of CO with herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt.



Source: Own

Fig. 6: Antimicrobial treatments of BAM with herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt.



Source: Own

Fig. 7: Antimicrobial treatments of CO/BAM with herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt.

Antimicrobial activity of the knitted fabrics treated with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. are shown in Table 5, and Figures 5-7 present examples of antimicrobial activity tests.

Tab. 6: Colour differences between the untreated, plasma pretreated and the knitted fabrics treated with a herbal extract of *Achillea millefolium* L. and *Reynoutria japonica* Houtt.

Type of knitted fabrics	Treatment	L	a	b	ΔE
CO	untreated	97.39	2.17	-9.30	/
	plasma	96.99	1.94	-8.73	0.734
	untreated + extract <i>Achillea millefolium</i>	67.24	-3.66	28.58	48.77
	untreated + extract <i>Reynoutria japonica</i>	70.65	12.25	51.71	67.37
	plasma	96.99	1.94	-8.73	/
	plasma + extract <i>Achillea millefolium</i>	74.02	-2.35	29.12	44.48
	plasma + extract <i>Reynoutria japonica</i>	69.41	13.21	54.30	69.71
	untreated + extract <i>Achillea millefolium</i>	67.24	-3.66	28.58	/
	plasma + extract <i>Achillea millefolium</i>	74.02	-2.35	29.12	6,93
	untreated + extract <i>Reynoutria japonica</i>	70.65	12.25	51.71	/
	plasma + extract <i>Reynoutria japonica</i>	69.41	13.21	54.30	3,02
BAM	untreated	96.27	1.87	-5.73	/
	plasma	96.34	1.61	-6.11	0,464
	untreated + extract <i>Achillea millefolium</i>	77.93	-1.53	22.08	33.49
	untreated + extract <i>Reynoutria japonica</i>	71.40	12.78	41.99	54.90
	plasma	96.34	1.61	-6.11	/
	plasma + extract <i>Achillea millefolium</i>	72.80	-0.768	28.23	41.71
	plasma + extract <i>Reynoutria japonica</i>	71.83	11.91	41.28	54.34
	untreated + extract <i>Achillea millefolium</i>	77.93	-1.53	22.08	/
	plasma + extract <i>Achillea millefolium</i>	72.80	-0.768	28.23	8,04
	untreated + extract <i>Reynoutria japonica</i>	71.40	12.78	41.99	/
	plasma + extract <i>Reynoutria japonica</i>	71.83	11.91	41.28	1.20
CO/BAM	untreated	96.73	2.12	-8.80	/
	plasma	96.64	1.88	-8.36	0.503
	untreated + extract <i>Achillea millefolium</i>	79.40	-1.94	24.32	37.60
	untreated + extract <i>Reynoutria japonica</i>	71.27	13.00	46.55	61.89
	plasma	96.64	1.88	-8.36	/
	plasma + extract <i>Achillea millefolium</i>	77.71	-0.217	30.72	43.48
	plasma + extract <i>Reynoutria japonica</i>	72.02	11.66	44.15	58.82
	untreated + extract <i>Achillea millefolium</i>	79.40	-1.94	24.32	/
	plasma + extract <i>Achillea millefolium</i>	77.71	-0.217	30.72	6.84
	untreated + extract <i>Reynoutria japonica</i>	71.27	13.00	46.55	/
	plasma + extract <i>Reynoutria japonica</i>	72.02	11.66	44.15	2.85

Source: Own

Water retention value (W_{rv}) as a parameter of sorption properties was not significantly changed after plasma pretreatment. However, the test results of W_{rv} after the treatment with alcoholic extract of *Achillea millefolium* L. indicate that there was a large reduction in W_{rv} in the knitted fabrics pretreated with plasma compared to the untreated ones (Table 3). This has confirmed that the surface modification with plasma enabled binding larger amounts of particles from alcoholic herbal extracts and thus reduced the number of groups capable of binding water. This is especially conspicuous in BAM, where the W_{rv} for plasma pretreated

samples decreased from 71.60% to 48.93% after treatment with the alcoholic extract of *Achillea millefolium* L.

Stereomicroscopic pictures showed that the plasma pretreatment mainly affected the degree of coloration for the fabrics treated with alcoholic extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. The only exception is plasma pretreated BAM, where the degree of coloration increased after the treatment with the alcoholic extract of *Achillea millefolium* L. (Table 4).

The SEM image of untreated cotton (Figure 2a) showed a typical grooved surface morphology with microfibrils oriented predominantly in the direction of the fiber axis. The outlines of the macrofibrils are still visible, and they are smooth and distinct due to the presence of an amorphous layer covering the fibre [8]. The surface of the water vapour plasma pretreated cotton is striped and cleaned, and a more distinct macrofibrilar structure is obtained (Figure 2b). From the SEM picture of BAM it is obvious that the plasma pretreatment changed the surface structure in comparison to the untreated one (Figure 3b). When cotton and bamboo knitted fabrics were pretreated with water vapour plasma, the quantity of the adsorbed particles of alcoholic extracts of *Achillea millefolium* L. was enlarged (Figures 2d, 3d, 4a and 4b). The results showed that plasma pretreatment heavily modified the morphology, surface and chemical properties of the knitted fabrics and they had an impact on the absorption of alcoholic herbal extracts into the knitted fabrics.

The investigation of the antimicrobial activity of the knitted fabrics treated with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria japonica* Houtt. against bacteria *Staphylococcus aureus* and *Escherichia coli* and yeast *Candida albicans* (Table 5) showed that the plasma pretreatment had an influence on the inhibition zones against *Staphylococcus aureus* for the knitted fabrics CO and BAM treated with the alcoholic extract of *Reynoutria japonica* Houtt. For the knitted fabrics CO/BAM only a contact inhibition was observed, i.e. there was no increase in the inhibition zones when comparing with CO and BAM. This can be connected with colour differences (Table 6), where it can be seen that in the knitted fabrics CO/BAM plasma pretreated and treated with the alcoholic extract of *Reynoutria japonica* Houtt. the degree of coloration was lower ($\Delta E = 58.82$) when compared to the untreated one ($\Delta E = 61.89$). It is known that the colour of herbal extracts and their antimicrobial effect come from substances with a different chemical composition (anthocyanins, anthraquinones, flavonoids, etc.) [9, 10]. These substances in combination with plasma surface modification, which affected the ability of wetting and coloration, improved the antimicrobial activity of the knitted fabrics treated with alcoholic herbal extracts. The alcoholic extract of the plant rhizomes and related species exhibit the antimicrobial activity against a number of microorganisms, which is slightly more pronounced against the gram positive bacteria [18]. In addition to the growth inhibition, which is dependent on the concentration, the alcoholic extract of rhizomes of *Reynoutria japonica* Houtt. significantly reduces the number of individual species of microorganisms [19]. Gram-negative bacteria are resistant to plant extracts due to the activity of efflux pumps [20], and the sensitivity of *Escherichia coli* in this experiment is smaller. Other studies have confirmed the sensitivity of *Staphylococcus aureus* and other Gram-positive bacteria against the alcoholic extract of *Achillea millefolium* L. [21, 22], yeast *Candida albicans* is poorly sensitive to most plant extracts [23].

Conclusion

The effect of plasma pretreatment on the structure and antimicrobial properties of the knitted fabrics treated with alcoholic herbal extracts of *Achillea millefolium* L. and *Reynoutria*

japonica Houtt. is presented with SEM pictures, water retention values, colour differences and inhibition zones. It can be concluded that:

- Plasma pretreatment had an effect on the reduction of sorption properties of the knitted fabrics treated with the alcoholic herbal extract of *Achillea millefolium* L. This pretreatment increased the zone of inhibition for the knitted fabric BAM against bacteria *Staphylococcus aureus*.
- In the treatment of the knitted fabrics with alcoholic herbal extract of *Reynoutria japonica* Houtt. it was possible to observe a positive effect of the plasma pretreatment on the antimicrobial properties. In the plasma pretreated knitted fabrics CO and BAM, the inhibition zone was increased against *Staphylococcus aureus*, but without any effect on *Escherichia coli* and *Candida albicans*.
- The degree of coloration was lower in the plasma pretreated knitted fabrics when compared to the untreated, and it was confirmed by measuring the colour differences. The differences in colour were acceptable for the knitted fabrics treated with the alcoholic herbal extract of *Reynoutria japonica* Houtt. because the value for ΔE ranged from 1.2 for BAM to 3.2 for CO (hardly perceptible differences). Significant colour differences ($\Delta E > 6$) were observed between the untreated and plasma pretreated samples and after treatment with the alcoholic extract of *Achillea millefolium* L., and the colour differences are not considered acceptable (not acceptable), i.e. the plasma pretreatment decreased the degree of coloration.

Acknowledgements

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Dr. Dragana Grujić; Dr. Aleksandar Savić; Dr. Ljiljana Topalić-Trivunović; Dr. Simona Jevšnik; Dr. Tatjana Rijavec; Dr. Marija Gorjanc

VLIV PLAZMOVÉ PŘÍPRAVY NA STRUKTURU A ANTIMIKROBIALNÍ VLASTNOSTI PLETENIN OŠETŘENÝCH BYLINNÝMI EXTRAKTY

V tomto příspěvku byl sledován vliv plazmové přípravy na strukturu a antimikrobiální vlastnosti pletenin (100% bavlna, 100% bambus a 50% bavlna / 50% bambusu) ošetřených alkoholickými bylinnými výtažky z řebříčku obecného a křídlatky japonské. Vliv plazmové přípravy na bázi vodní páry na povrchovou funkčnost nebo na změny struktury pletenin se hodnotí pomocí SEM. Antimikrobiální vlastnosti pletenin ošetřených bylinnými extrakty byly testovány na Escherichia coli, Staphylococcus aureus a Candida albicans za pomoci paralelní pruhovací metody (AATCC TM 147 - 2004). Stupeň zabarvení byl hodnocen metodou CIELAB a stereomikroskopem. Bylo zjištěno, že plazmová příprava a zpracování za použití bylinného výtažku z křídlatky japonské mělo pozitivní dopad na antimikrobiální ochranu pletenin proti Staphylococcus aureus.

EINFLUSS DER PLASMABEHANDLUNG AUF DIE STRUKTUR UND DIE ANTIMIKROBIELLEN EIGENSCHAFTEN VON STRICKWAREN, DIE MIT KRÄUTEREXTRAKTEN BEHANDELT WURDEN

In diesem Beitrag wurde der Einfluss von Plasmabehandlung auf die Struktur und die antimikrobiellen Eigenschaften von Strickwaren (100% Baumwolle, 100% Bambus, 50% Baumwolle / 50% Bambus), die mit alkoholischen Kräuterextrakten aus Achillea millefolium L. und Reynoutria japonica Houtt behandelt wurden, untersucht. Der Einfluss der Plasmabehandlung auf Basis vom Wasserdampf auf die Oberflächenfunktionalisierung oder auf Strukturveränderungen von Strickwaren wurde mit Hilfe von SEM bewertet. Die antimikrobiellen Eigenschaften der mit Kräuterextrakten behandelten Strickwaren wurden auf Escherichia coli, Staphylococcus aureus und Candida albicans mit Hilfe des parallelen Streifenverfahrens (AATCC TM 147 – 2004) getestet. Die Menge an Verfärbung wurde mit dem CIELAB Modell und mit dem Stereomikroskop beurteilt. Man stellte fest, dass die Plasmabehandlung und die Bearbeitung mit Hilfe des Extraks aus Reynoutria japonica Houtt. einen positiven Einfluss auf den antimikrobiellen Schutz der Strickwaren gegen den Staphylococcus aureus hatte.

WPŁYW PRZYGOTOWANIA PLAZMOWEGO NA STRUKTURĘ I WŁAŚCIWOŚCI ANTYMIKROBOWE DZIANIN USZLACHETNIONYCH WYCIĄGAMI Z ZIÓŁ

W niniejszym artykule badaniem objęto wpływ przygotowania plazmowego na strukturę i właściwości antymikrobowe dzianin (100% bawełna, 100% bambus i 50% bawełna / 50% bambus) uszlachetnionych alkoholowymi wyciągami z ziół - krwawika pospolitego i rdestowca ostrokończystego. Wpływ przygotowania plazmowego na bazie pary wodnej na funkcje powierzchni lub zmiany struktury dzianin ocenia się przy pomocy SEM. Antymikrobowe właściwości dzianin uszlachetnionych wyciągami z ziół testowano na Escherichii coli, Staphylococcus aureus i Candida albicans przy pomocy równoległej metody paskowej (AATCC TM 147 – 2004). Stopień ubarwienia oceniano przy pomocy metody CIELAB i stereomikroskopu. Stwierdzono, że przygotowanie plazmowe i uszlachetnienie wyciągiem z rdestowca ostrokończystego wpłynęło pozytywnie na antymikrobową ochronę dzianin przed Staphylococcus aureus.