HYDROGELS-BASED TEXTILE MATERIALS FOR TREATMENT OF FIRST-DEGREE BURN INJURIES

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Hydrogels based on collagen and xanthan have found various applications as drug delivery carriers. The main strategy is to combine the traditional perspective of using essential oils with polymeric hydrogels in order to develop a potential dressing that provides wound healing for first-degree burn injuries. In this regard, the present study is aimed to develop textile materials with potential for use in the treatment of first-degree burn injuries by approaching the hydrogels based on xanthan gum and collagen as polymeric matrix loaded with essential oils (cinnamon essential oil, tea tree essential oil), propolis (hydroglyceric extract or with content of colloidal silver) and drugs (chlorhexidine, ciprofloxacin). A total of six experimental variants of hydrogels were synthesized and then were applied by padding method on a plain weave textile structure from 100% cotton. The functionalized textile materials were characterized by morphological and antibacterial point of view. The textile materials treated materials with all synthesized hydrogels based on xanthan and collagen as polymeric matrices have antibacterial activity against *S. aureus* and *E. coli* test strains, the highest inhibition zone was provided by the samples loaded with ciprofloxacin (MUP3 and MUP4 code).

Keywords: first-degree burn injuries, bioactive principles, hydrogels

INTRODUCTION

Burns are a prevalent and burdensome critical care problem. The priorities of specialized facilities focus on stabilizing the patient, preventing infection, and optimizing functional recovery (Rowan *et al*., 2015). Associated infection with burn is the main cause of mortality in patients with extensive burns. Therefore, appropriate management of burn wounds within short time is required.

Propolis is used extensively in folk remedies for treatment of burns and wounds as it shows good healing potential, skin cell proliferation properties and growth capacity (Balata *et al*., 2018). A large amount of surveys and experimental evidence sustain plant beneficial properties on wound healing as well as on a wide range of skin diseases. Essential oils derived from plants offer an alternative to aid wound and burn healing. Strong evidence about essential oils anti-inflammatory and antimicrobial properties is thoroughly described in literature (Perez-Recalde *et al*., 2018). Also, use of antibiotics in people with infected burn wounds is more complicated than in other diseases. This is because the pharmacokinetic parameters of antibiotics (absorption, distribution, metabolism and excretion) are altered in the burned person, and significant variations exist between individuals (Lu *et al*., 2017).

The aim of this study is to obtain biomaterials with potential use in the treatment of first-degree burns injuries, by approaching the immobilization on 100% cotton fabric of hydrogels based on collagen-xanthan as polymeric matrix which embedding different active principles.

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EXPERIMENTAL PART

Materials

Bleached 100% cotton woven fabric with the weight of 168 g/m^2 has been used for all experiments. Collagen (*ZENYH, Romania*) and xanthan (*Xanthomonas campestris*, *Sigma Aldrich*) were used as embedding agents for the bioactive principles. Ciprofloxacin (Sigma Aldrich), chlorhexidine digluconate (Sigma Aldrich), propolis (propolis extract – hydroglyceric solution 60%, propolis extract 48% – with colloidal silver 50 ppm, *Dacia Plant, Romania*), cinnamon essential oil (*HerbalSana, Romania)* and tea tree essential oil (*Mayam, Romania*) were used as bioactive agents. Tween 80 (*Sigma Aldrich, Germany*) was used as surfactant and glycerol (*Riedel-de haën|Honeywell, USA*) has been used as a solubilizing agent. Calcium chloride (anhydrous, *Fluka|Honeywell, USA*) was used as a cross-linking agent.

Synthesis of the Hydrogels

Firstly, stock solutions of 5% collagen and 1% xanthan were prepared and then mixed (15 mL collagen and 15 mL xanthan) under magnetic stirring for 30 minutes. Thus, over the previously prepared polymeric matrix, 0.2 g ciprofloxacin or 4 mL chlorhexidine (20 µL/mL) were added, the magnetic stirring continuing for another 30 minutes. In order to improve the flexibility of the hydrogels, 7.5 mL of glycerin were added to the resulting mixture. Further, 0.9 mL essential oil (cinnamon essential oil or tea tree essential oil) and 4 mL Tween 80 were added dropwise and separately on the previously prepared mixture, maintaining the magnetic stirring for 15 minutes. 4 mL propolis were then added on the resulted mixture, the magnetic stirring continuing for 30 minutes. 0.15 mL of 5 % calcium chloride solution were added as a cross-linking agent, as a final step of the hydrogel`s synthesis. The selected experimental variants are presented in Table 1.

Table 1. The bioactive principles used for each experimental variant

Code	Drugs		Essential Oils		Propolis	
	Chlorhexidine	Ciprofloxacin	Tea Tree	Cinnamon	Hydroglyceric solution	Colloidal Ag
MUP 1	x		x	x	x	
MUP 2	x		x	x		x
MUP 3		x	x	x	x	
MUP 4		x	x	x		x
MUP 5	x		x		x	
MUP 6	x			x	x	

Functionalization treatments

The obtained hydrogels were immobilized on the textile materials by the padding method on the laboratory padder (Roaches, UK) at 85% wet pick-up. The treated textile materials were then subjected to the drying operation at 50˚C for 3 minutes on the drying/curing/ heat-setting unit, model TFO/S 500 mm (Roaches, UK).

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Methods

pH Value

The pH value of hydrogels was measured using the Multiparameter benchtop meter inoLab® Multi 9310 IDS.

Scanning Electron Microscopy

Visualization of the morphology of the cotton fiber surfaces was performed by using Quanta 200 electron microscope (*FEI, The Netherlands*).

Hydrophilicity and Comfort Indices of Functionalized Textile Materials

Hydrophilicity of functionalized textile materials was evaluated according to Romanian Standard SR 12751-89 determining fabric wettability by drop method. The water vapor permeability was performed according to STAS 9005:1979 standard and the air permeability was performed according to SR EN ISO 9237:1999 standard.

Antimicrobial Activity

The antibacterial activity of the samples was qualitatively assessed by the Agar diffusion method according to the SR EN ISO 20645:2005 standard - Determination of antibacterial activity-agar diffusion plate test, by using cultures in liquid medium replicated at 24 hours of ATCC 6538 *S. aureus* and ATCC1 1229 *E. coli* test strains. Inhibition zones were calculated using the following formula:

$$H = (D - d)/2 \quad (1)$$

where: H – the inhibition zone [mm]; D – the total diameter of specimen and inhibition zone [mm]; d – the diameter of specimen [mm].

The criteria for evaluation the inhibition zones according to the standard SR EN ISO 20645:2005 are presented in Table 2.

Table 2. Criteria for inhibition zones according to the SR EN ISO 20645:2005 standard

Inhibition zone [mm]	Growth	Evaluation
>1 1-0 0	absence	satisfactory effect
0	little	efficiency limit
0	moderate important	unsatisfactory effect

RESULTS AND DISCUSIONS

pH Value

The pH values of synthesized polymeric systems are presented in Table 3. The pH of the polymeric solutions is between 5.50 – 5.88, being within the accepted limits for the field of application. It is known from the literature that the skin without any injuries has a pH between 4 - 6 and the wound can have a pH of up to 8.9.

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Table 3. The pH values of the hydrogels

Code	pH value
MUP1	5,62
MUP2	5,55
MUP3	5,86
MUP4	5,88
MUP5	5,50

Scanning Electron Microscopy

The electronic images obtained at a magnification of x2000 for the textile materials treated with the bioactive systems are presented in the Figure 1.

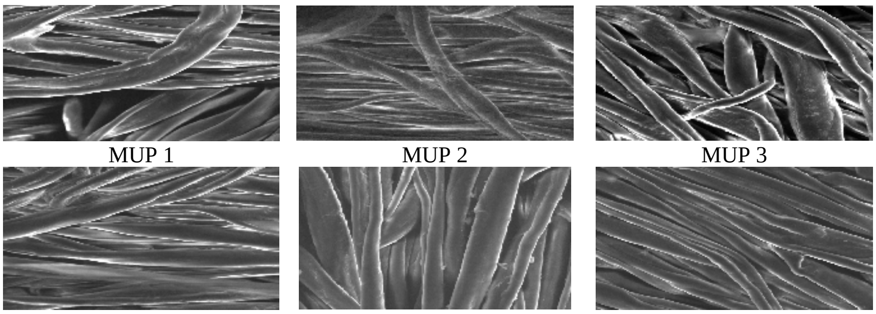

Figure 1. SEM images for functionalized textile materials

The resulting micrographs reveal that the surface of the fibers is covered with a thin polymeric layer that is uniformly distributed both on the surface of the fibers and inside the space between the fibers.

Hydrophilicity and Comfort Indices

The values obtained for hydrophilicity and comfort indices are shown in Table 4.

Table 4. Hydrophilicity and comfort indices of the functionalized textile materials

Code	Water vapor permeability [%]	Air permeability [l/m^2/s] 100 Pa	Air permeability [l/m^2/s] 200 Pa	Hydrophilicity [s]
M	30.52	362.2	481.3	immediate
MUP 1	26,79	246,6	452,8	immediate
MUP 2	25,56	257,2	472	immediate
MUP 3	26,97	245,6	454,2	immediate
MUP 4	26,62	242,8	447,8	immediate
MUP 5	28,91	256,6	476,6	immediate
MUP 6	28,91	251,2	460,4	immediate

Analyzing the values obtained for air and water vapor permeability, it is found that the functionalization treatments carried out lead to a decrease of these comfort indices for all of experimental variants, there are small insignificant variations between the

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analyzed variants. In addition, the textile biomaterials possess an excellent moisture absorption capacity.

Antimicrobial Activity

Images of Petri plates after 24h incubation are shown in Figure 2 and an assessment of antibacterial activity is shown in Table 5.

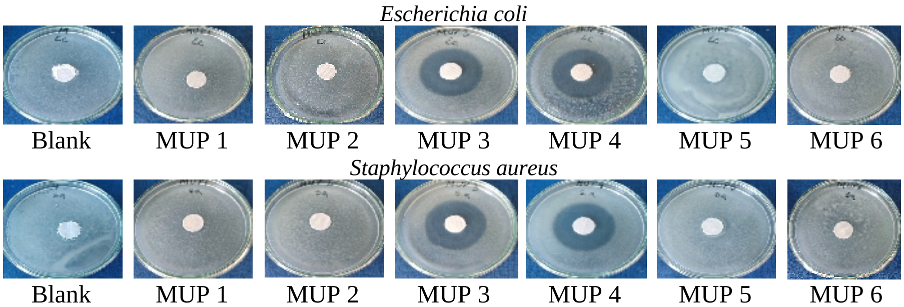

Figure 2. Images of Petri plates showing antibacterial effect after 24 h of incubation

Table 5. Evaluation of the antibacterial activity

Code	Inhibition zone (mm)		Evaluation	
	E. coli	*S. aureus*	*E. coli*	*S. aureus*
M	0	0	Unsatisfactory effect	Unsatisfactory effect
MUP 1	1.5	2	Satisfactory effect	Satisfactory effect
MUP 2	0.5	0*	Satisfactory effect	Satisfactory effect
MUP 3	18	19	Satisfactory effect	Satisfactory effect
MUP 4	17.5	16	Satisfactory effect	Satisfactory effect
MUP 5	0	0	Satisfactory effect	Satisfactory effect
MUP 6	0	0	Satisfactory effect	Satisfactory effect

**Absence of multiplication - even without the inhibition zone - can be considered as a positive effect because the formation of such an inhibition zone can be prevented by a small diffusion of the active substance*

According to ISO 20645 standard method, in the case of no inhibition zone (0 mm), without bacterial growth in the nutrient medium under the specimen, the antibacterial effect is evaluated as “satisfactory”, which indicates antimicrobial activity. By analyzing the obtained results, it can be concluded that the most pronounced antibacterial effects were obtained in the case of the textile materials treated with hydrogels containing ciprofloxacin (code MUP3 and code MUP4) in comparison with the samples treated with hydrogels which containing chlorhexidine (code MUP1 and code MUP2). Also, the biomaterial obtained by treating of the textile material with the hydrogel based on collagen-xanthan-ciprofloxacin-tea tree essential oil-cinnamon essential oil-propolis (hydroglyceric solution), code MUP3, shows the greatest antibacterial effect, with inhibition zones of 18 mm for *E. coli* test strain and respectively 19 mm for the *S. aureus* test strain.

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CONCLUSIONS

The main goal of this study was to develop textile biomaterials designed for the treatment of first-degree burns injuries, by embedding different therapeutic agents on the textile materials through an appropriate carrier system. The obtained functionalized textile materials were analyzed by using physical-mechanical tests (comfort indices) scanning electron microscopy, hydrophilicity (drop method) and antibacterial tests. The overall results suggest that the functionalization treatments lead to a decrease of comfort indices for all of experimental variants, being registered small insignificant variations between the analyzed variants. Also, the obtained biomaterials showed an excellent moisture absorption capacity and an antibacterial effect which was proved against *E. coli* and *S. aureus* test strains.

These overall results indicate that incorporating these active principles into the polymeric matrix can significantly enhance the potential efficacy of the fabrics as dressing designed for treatment of first degree burn injuries.

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