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# TEXTILE STRUCTURES WITH ANTI-INFLAMMATORY PROPERTIES FOR THE TREATMENT OF BURN INJURIES

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***Abstract:*** *The development of multilayer medical devices with composite characteristics, usable for basic medical interventions on superficial burns involves an interfacing layer with the lesion that is non-adherent, biologically inert and microporous and the outer layer acts as a carrier, insulator and protector of the underlying layers, being elastic, resistant and submicro-porous (to block the physical access of microorganisms to the lesion). These layers were made by classical and nonconventional textile technologies (weaving and nonwovens technology) using natural fibers (100% cotton, 100% bamboo) and artificial fibers (100% lenpur) with contemt of active substances (chitosan, Zn). Biocompatibility tests performed by two standardized methods, namely the MTT cell viability test and the LDH cell integrity test planned to identify and quantify the possible harmful effect of the presence of textile samples on cells culture. Evaluation of the antimicrobial activity is performed in order to establish the safety of the biomedical use of the materials, or verification of the efficiency of their use in infection control and decontamination processesn. Evaluation of the antimicrobial activity of the samples was performed by determining the logarithmic and percentage reduction of some microbial populations. For testing, the following standardized strains were used: Staphylococcus aureus ATCC 6538, Escherichia coli ATCC 8739 and Candida albicans ATCC 10231. The textile structures that provided the most effective antibacterial effect were those incorporating chitosan and Tencel fibres, which provided percentage reductions in Escherichia coli (Gram-negative bacteria) populations of about 76%, lower than those against Staphylococcus aureus (Gram-positive bacteria) of 90%.*

***Key words:*** active substances, infection, tissue, biocompatible, antimicrobial, decontamination.

## 1. INTRODUCTION

Severely burned skin stops to fulfill its natural role of protection and barrier and promotes a dramatic increase in water loss and can become a gateway for bacterial invasion. It seems that the activation of a proinflammatory cascade after a burn plays an important role in the development of a subsequent immune dysfunction, bacterial translocation in the intestine, susceptibility to sepsis and multiple organ failure [1]. A local response to a burn involves not only direct tissue coagulation, but also tissue conversion, a process in which damaged cells, rather than recovering, progress to cell death, extending the depth and severity of the initial lesion. The systemic response to burns is caused by the loss of the skin barrier and the release of vasoactive mediators from the wound and subsequent infection. When the size of the burn exceeds about 25% of the body surface, interstitial edema develops in organs and soft tissues, mainly as a side effect of a combination of mediators

released by wounds and hypoproteinemia [2]. Thermal damage cause a massive release of proinflammatory cytokines, chemical mediators including histamine, complement, arachidonic acid, coagulation cascade products, and oxygen free radicals, which increase vascular permeability leading to hypovolemia and acute kidney failure. This can be complicated by systemic inflammatory response syndrome and marked immune suppression. Subsequent wound infection and bacterial translocation from the gastrointestinal tract promote sepsis. This adds to the final common path to multi-organ failure and death [3].

## 2. MATERIALS AND METHOD

The development of multilayer medical devices with composite characteristics, usable for basic medical interventions on superficial burns with thermal origin (flame and melts) occurred on anatomical regions protected by clothes (so except face and eyes) involves textile structures with such characteristics that ensure antimicrobial and analgesics effects, as well as fluid management in the injured region, through local transfer processes (sorption/ desorption in porous media) [4].

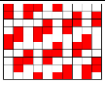
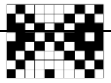
The interfacing layer with the lesion must be non-adherent, biologically inert and microporous and the outer layer acts as a carrier, insulator and protector of the underlying layers, being elastic, resistant and submicro-porous (to block the physical access of microorganisms to the lesion). These layers were made by classical and nonconventional textile technologies (weaving and nonwovens technology) using natural fibers (100% cotton, 100% bamboo) and artificial fibers (100% Lenpur) with contemt of active substances (chitosan, Zn). Biocompatibility tests performed by two standardized methods, namely the MTT cell viability test and the LDH cell integrity test planned to identify and quantify the possible harmful effect of the presence of textile samples on cells culture [5]. To consider that a particular sample is biocompatible, the optical density values for MTT tests must be higher than those of the LDH quantification test (in other words, a sample is biocompatible if the number of viable, metabolically active cells is greater than the number of dead cells).

Evaluation of the antimicrobial activity is performed in order to establish the safety of the biomedical use of the materials, or verification of the efficiency of their use in infection control and decontamination processes [6]. Evaluation of the antimicrobial activity of the samples was performed by determining the logarithmic and percentage reduction of some microbial populations. For testing, the following standardized strains were used: *Staphylococcus aureus* ATCC 6538, *Escherichia coli* ATCC 8739 and *Candida albicans* ATCC 10231.

## 3. RESULTS

5 variants of woven fabrics and 3 variants of nonwoven fabrics were made. The main design parameters are shown in table 1 and 2.

***Table 1:*** *The main design parameters for woven fabrics*

| Woven fabric codification | Design parameters | | | | | Pattern |
|---|---|---|---|---|---|---|
| | Yarn type | | Yarn count | | Weft set [yarns/10 cm] | |
| | Warp | Weft | Warp | Weft | | |
| BZNT1 | 100% cotton | 80% cotton/ 20% fibres with ZnO | Nm 50/2 | Nm 68/2 | 240 |  Derivated patterns |
| BBT1 | 100% cotton | 100% bamboo | Nm 50/2 | Nm 34/1 | 250 |  |

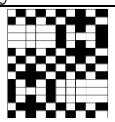
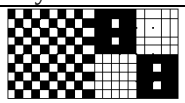
| | | | | | | |
|---|---|---|---|---|---|---|
| BLT1 | 100% cotton | 100% Lenpur | Nm 50/2 | Nm 34/1 | 200 | Honeycomb weave 1 |
| BAT1 | 100% cotton | 100% Tencel | Nm 50/2 | 130 dtex | 350 |  Honeycomb weave 2 |
| BBT2 | 100% cotton | 100% cotton | Nm 50/2 | Nm 60/2 | 255 |  Combined patterns |

***Table 2:*** *The main design parameters for nonwoven fabrics*

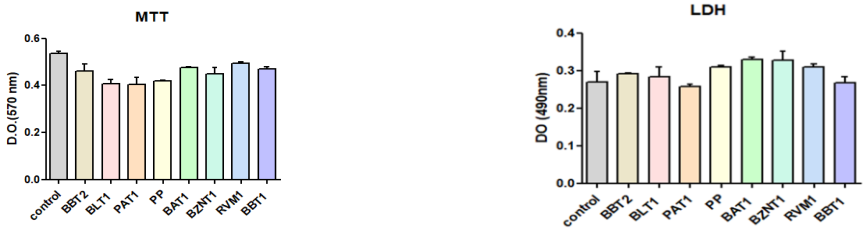
| Parameter | Variant | | |
|---|---|---|---|
| | C1 | C2 | C3 |
| Yarn type | 100% chitosan | 50/50 chitosan/viscose | 20/80 chitosan/viscose |
| Weight, g/mp | 108.16 | 54.68 | 43.12 |
| Thickness, mm | 1.38 | 0.3 | 0.23 |
| Breaking strength lengthwise/crosswise, N | 35.39/ 44.07 | 33.37/ 45.64 | 57.42/ 70.70 |
| Elongation at break, lengthwise/crosswise, % | 54.37/ 45.37 | 33.05/ 43.34 | 29.19/ 44.2 |
| Tear resistance, lengthwise/crosswise, N | 9.1/ 9.11 | 4.29/ 4.43 | 6.96/ 7.49 |
| Absorption capacity, % | 92 | 308 | 198 |
| pH | 8.2 | 8.3 | 8.2 |

### 3.1 Evaluation of biocompatibility

Fig. 1 shows the results of the MTT and LDH tests applied to the textile samples subjected to characterization. Fig. 2 comparatively compares the results of quantifying the optical density of samples subjected to MTT and LDH tests, and fig. 3 is dedicated to samples with chitosan content.


***Fig. 1:*** *The result of biocompatibility tests applied to textile samples*

After 72 hours of cultivation, the proliferation of co-cultivated L929 cells in the presence of textile samples was similar to the proliferation of the control sample (L929 cells, unstimulated). The cytotoxicity of the samples was investigated by the LDH test to quantify the level of LDH enzyme released into the culture environment from dead cells. No statistically significant differences were found between LDH levels compared to the control sample.




a. b.

***Fig. 2:*** *Comparative value of optical densities*


a. b.

***Fig. 3****: Comparative value of optical densities*

The samples BAT1 and BZNT1 showed a higher degree of cytotoxicity, according to the LDH test (Fig. 2.b). In the case of textile samples including chitosan, there was an increase in cell proliferation (Fig. 3). According to the comparative determinations MTT and LDH, variant C3 showed the highest biocompatibility, similar to that of the cells in the control sample, unstimulated.

### *3.2 Evaluation of antimicrobial activity*

Evaluation of the antimicrobial activity of the samples was performed by determining the logarithmic and percentage reduction of *Staphylococcus aureus*, *Escherichia coli* and *Candida albicans* microbial populations.

The diagrams presented in fig. 4 indicate the values obtained for the 2 parameters in relation to the *Staphylococcus aureus* (Gram-positive bacteria). For the tested variants, logarithmic reductions between 0.26 and 0.87 were obtained. The variants of textile structures that ensure the most effective antibacterial effect are those that include chitosan, along with the 100% cotton sample (BBT2). The presence of Tencel fiber combined with chitosan fiber amplifies the antibacterial effect of the blending, ensuring percentage reductions of the *S. aureus* population close to 90%, a value considered as a reference in inhibiting bacterial cultures.

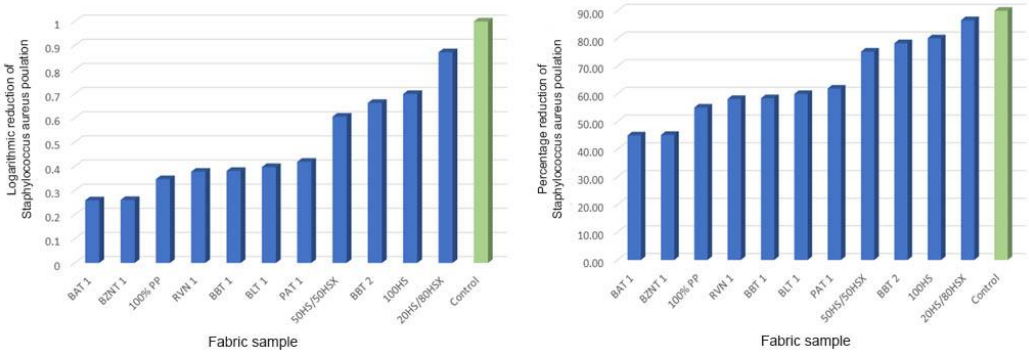



***Fig. 4:*** *Logarithmic and percentage reduction of the Staphylococcus aureus population*

The diagrams presented in fig. 4 indicate the values obtained for the 2 parameters in relation to *Escherichia coli* bacteria (Gram-negative bacteria). Logarithmic reductions between 0.25 and 0.63 were obtained. The textile samples that provide the most effective antibacterial effect are those that include chitosan, along with Tencel fibers, which provide a percentage reduction in the *Escherichia coli* (Gram-negative bacteria) population of about 76%, but lower than those against *Staphylococcus aureus* (Gram-positive bacteria).

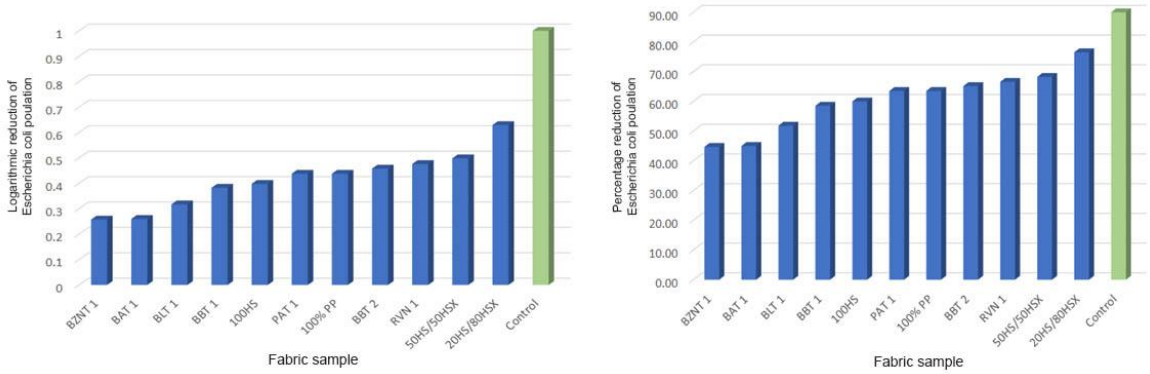



***Fig. 5**: Logarithmic and percentage reduction of the Escherichia coli population*

In fig. 6 este prezentata expresia grafica a valorilor obtinute pentru cei doi parametrii in raport cu
Bacteria. Reducerile logaritmice obtinute sunt cuprinse intre 0,33 si 0,66, iar reducerile procentuale intre 53 si 78 %. Si in cazul inhibarii dezvoltarii *Candida albicans*, varianta BZNT1 este ceea mai eficienta in reducerea populatiilor fungice.

The diagrams presented in fig. 6 indicate the values obtained for the 2 parameters in relation to bacteria. The logarithmic reductions obtained are between 0.33 and 0.66, and the percentage reductions between 53 and 78%. In the case of inhibiting the development of Candida albicans, the BZNT1 variant is the most effective in reducing fungal populations, as well.

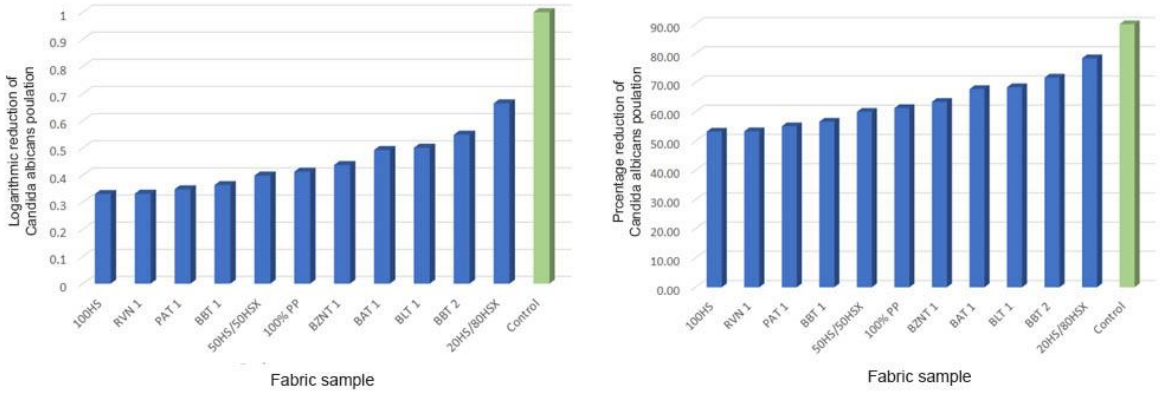



***Fig. 6:** Logarithmic and percentage reduction of the Candida albicans population*

## 4. CONCLUSIONS

- The variant of nonwoven fabric made of 20% chitosan/ 80% viscose recorded the highest biocompatibility similar to that of the cells in the control sample, unstimulated. This fabric also

obtained the best results in antimicrobial tests, being qualified for the interfacing with the injury due to burns of the multilayer structure.

- Woven fabrics variants BAT1 and BZNT1 showed a higher degree of cytotoxicity, these qualifying for the outer layer with the role of carrier, insulator and protector of the underlying layers of the multilayer structure.

- Although the antimicrobial activity of all textile samples is moderate, the final biomedical application of textiles should be considered. Because they are intended to be used as medical devices (hemostatic support), their antimicrobial properties are only needed until systemic antibiotic treatment is in action (about. 4-5 hours after application). Percentage microbial reductions of over 50% are considered optimal for the targeted application.

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