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Proceedings

Biodegradable fibers modified with natural agents for potential applications in the treatment of wound infections†

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Abstract: The increase in bacterial resistance to antibiotics is a global concern that conditions and puts the lives of many patients at risk. Natural extracts are emerging as potential alternatives to the use of antibiotics to fight infections, by exhibiting excellent antimicrobial and anti-inflammatory profiles. Thymol, eugenol, carvacrol and propolis have been explored in the prevention/treatment of infections present in wounds, revealing great effectiveness against bacteria. In addition, different fiber-based scaffolds have been employed in the treatment of wound infections because of their similarities to the fibrillar elements that make up the structure of the skin.

Keywords: natural biomolecules; biodegradable microfibers; infection control

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1. Introduction

The skin is an organ with an intricate structure that is divided into different layers. Any change in the structure of the skin can trigger the appearance of a wound. In some cases, those wounds are associated with bacterial infections (1,2). It is known that antibiotics are the main method of treating infections, especially those caused by bacteria. Although these are effective, they are responsible for bacterial resistance to various drugs (3,4). To combat this problem, natural extracts of increased therapeutic potential have awakened growing interest in the prevention and treatment of infections, reducing the environmental impact associated with antimicrobial agents' production (5). These biomolecules have good antimicrobial, antioxidant and anti-inflammatory properties (4,6).

The wet-spinning technique is based on the principle of phase inversion induced by a non-solvent. In this technique, the polymer solution is injected into a specific coagulation bath composed of a non-polymer solvent, which causes the extruded material to precipitate in the form of a filament (microfiber). This method is very versatile and allows the use of both synthetic and natural polymers for the production of fibers (5,7). Furthermore, wet-spun fibers are microfibers capable of 3D network formations that allow cellular interaction (8). In the present study, microfibers of polycaprolactone (PCL) were processed by wet-spinning and loaded with selected natural extracts with the purpose of being explored as platforms for combating bacterial infections present in wounds.

2. Materials and Methods

Fiber production and examinations were divided in three steps. In Figure 1, the general objective of this study is represented in a simplified way.

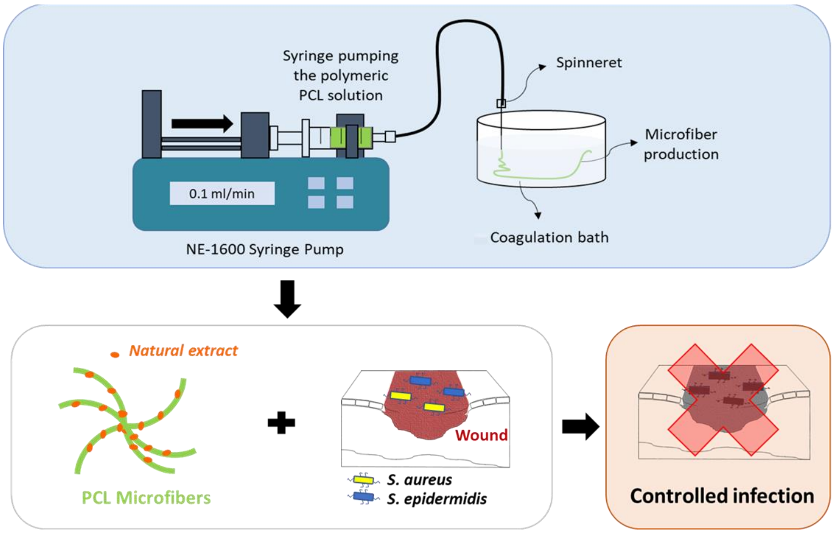

Figure 1. Schematic representation of the production of PCL microfibers loaded with natural extracts and antimicrobial action against *Staphylococcus aureus* (*S. aureus*) and *S. epidermidis* bacteria.

2.1. Polymeric Solution Preparation

Polymers—polycaprolactone (PCL, Mn = 80,000).
Solvents—dimethylformamide (DMF).
Solubilization conditions—1 h at 50 °C and 300 rpm.

2.2. Wet-spinning Processing Conditions

Flow rate—0.1 mL/min.
Needle Gauge—18.
Coagulation bath—distilled water (dH_2O).
Temperature of extrusion—19 to 21 °C.

2.3. Minimum Inhibitory Concentration Studies

EOs— Thymol, eugenol, carvacrol and propolis.
Bacteria—Staphylococcus aureus (ATCC 6538) and Staphylococcus epidermidis (ATCC 35984).
Concentration— $5x10^6$ CFUs/mL in Muller Hinton Broth (MHB).
Incubation period—24 h.

3. Results and Discussion

EOs were examined individually for their antimicrobial action against the Gram-positive bacteria *S. aureus* and *S. epidermidis*. Thymol was considered the most effective from the four EOs, with MIC values of 0.313 and 0.627 mg/mL against the bacteria *S. aureus* and *S. epidermidis*, respectively. On its turn, propolis required 2.560 mg/mL to inhibit the growth of both bacteria, while in case of carvacrol, this extract needed 2.560 and 5.120 mg/mL to inhibit the growth of these bacteria, respectively. From the tested group, eugenol required the highest concentrations, 5.120 mg/mL, to induce the same effects in both bacteria.

Using the wet-spinning technique, the PCL microfibers were successfully produced. To generate modified fibers, the PCL solution was combined with thymol (dissolved in dimethyl sulfoxide) at 1.254 mg/mL (2×0.627 mg/mL; 2×MIC). Both unloaded and thymol-loaded PCL-based fibers had a uniform and homogeneous appearance (Figure 2), although the presence of thymol reduced the elongation at break (≈ 159.32 to ≈ 93.26%) and diameter of the fibers (≈ 247.49 to ≈ 146.99 µm).

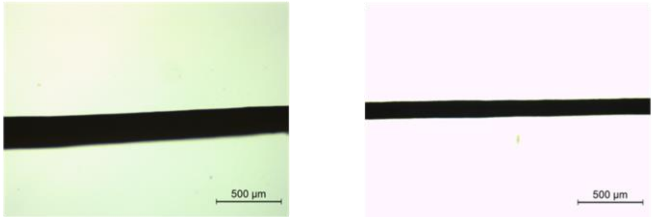

Figure 2. Example of the morphology of microfibers unloaded (left) and loaded (right) with thymol, captured at 5× magnification using a brightfield microscope (scale bar = 500 μm).

4. Conclusions

According to data, each of the four natural extracts is efficient against Gram-positive bacteria *S. aureus* and *S. epidermidis*. However, thymol proved to be the most effective, and for this reason it was immobilized on PCL fibers. With and without thymol immobilization, the fibers displayed a uniform and homogeneous aspect. It was also observed that the presence of this biomolecule worsens the elongation at fiber break and reduces its diameter. Future work will focus on using individual PCL fibers with incorporated thymol to produce a dressing with antibacterial characteristics.

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Conflicts of Interest: The authors declare no conflict of interest.

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