Natural Polymeric (Polylactic Acid (PLA) and Lignin) Membranes manufactured by Casting Solution and Electrospinning with Antimicrobial Applications

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INTRODUCTION & AIM

Nowadays, membrane technology is contributing to significative improvements in various fields, including sensors (aniline[1], ozone[2], etc.), and water treatment technology (through the absorption of heavy metals like Cr[3]), and antimicrobial applications[4],[5]. In many applications the bacterial growth in the membrane is a real concern.

The main goal of this work is to develop antimicrobial membranes using natural polymers—polylactic acid (PLA) and lignin—optimized through two fabrication techniques: Solution Casting (SC) and Electrospinning (EC).

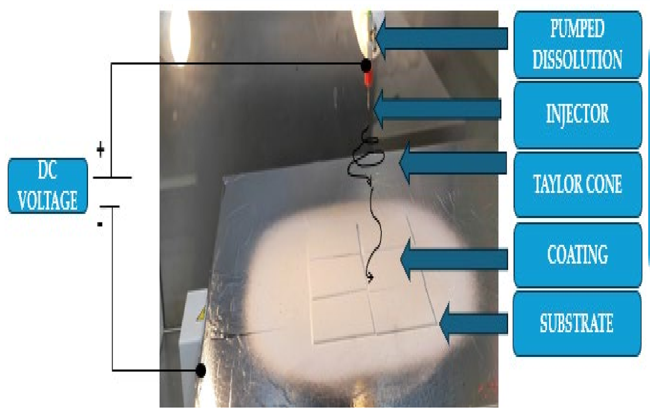
This research aligns with the Sustainable Development Goals (SDGs) outlined in the 2030 Agenda, specifically targeting Goal 3 (Good Health and Well-being) and Goal 13 (Climate Action).

METHOD

Polymeric dissolution = Dichloromethane/Acetone 4:1 (10 mL Dichloromethane) +

- ES: 10 %wt (PLA-Lignin 95:5) powders; 12 %wt PLA powders
- SC: 9 %wt (PLA-Lignin 95:5) powders; 9 %wt PLA powders

The dissolution was dissolved using a magnetic stirrer for 24 hours, at lab temperature (22ºC)



Electrospinning setup for the PLA+Lignine membranes over glass substrates (72x52 mm)

ES: 10 mL of dissolution (Syringe 14.4 mm inside diameter) using a commercial electrospinning machine, with the next parameters:

Distance INJECTOR - SUBSTRATE: 20 cm
VOLTAGE: COLECTOR (-3 kV) e INJECTOR (+4,5 (kV)
FLOW RATE: 1 mL/h
DURATION: 60 minutes
TEMPERATURE(22ºC) [There were not humidity control]

SC: 1.5 mL, 2 mL and 2,5 mL were added to a glass substrate (circular geometry (internal diameter 4 cm).

The solvent evaporated for 48 hours, at lab temperature (22ºC) [No humidity control]

For Electrospinning one solution was prepared for PLA (Only) and PLA+Lignin (Apart) and for Solution casting the same process

Once the membranes were obtained and superficially characterised, the **antimicrobial activity in direct contact method** was carried out {**ASTM E2149 [6]**}

Against: ***Escherichia Coli*** (Gram negative), ***Staphylococcus Aureus*** (Gram positive), ***Staphylococcus Epidermis***(Gram positive), ***Micrococcus Luteus***(Gram positive)

9 %wt PLA SC | 9 % PLA+Lignin SC | Negative control sample (clean glass) | 10 %wt PLA+Lignin ES | 12 %wt PLA ES

100 µL of pathogen inoculums was added

For 24 hours, at 37ºC

X4 (Once for each pathogen)

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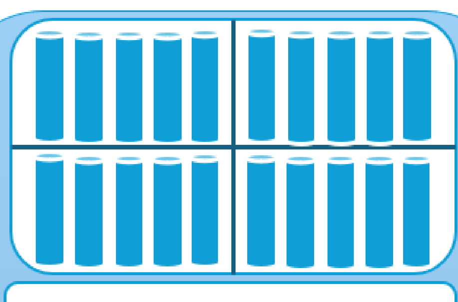
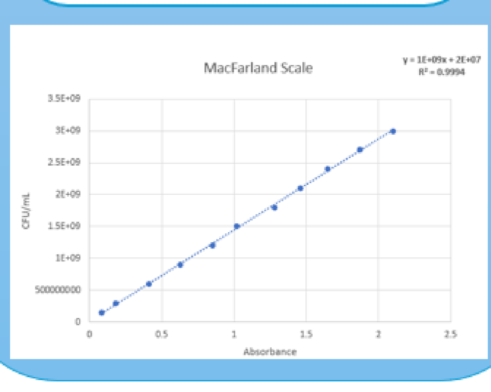


For 24 hours, at 37ºC

UV-Visible absorbance was measured [0,3,6,9,12,24 hours]

Comparing the absorbance with CFU (MacFarland Scale)



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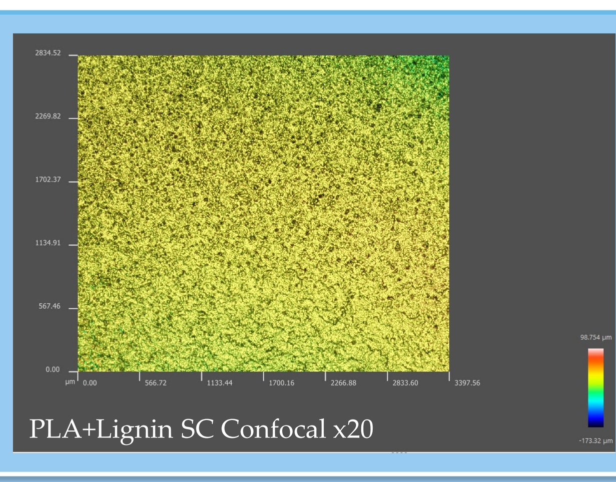
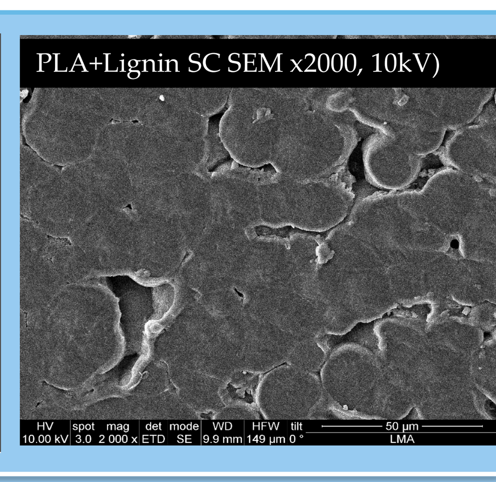
9 %wt PLA SC | 9 % PLA+Lignin SC | Negative control sample (clean glass) | 10 %wt PLA+Lignin ES | 12 %wt PLA ES

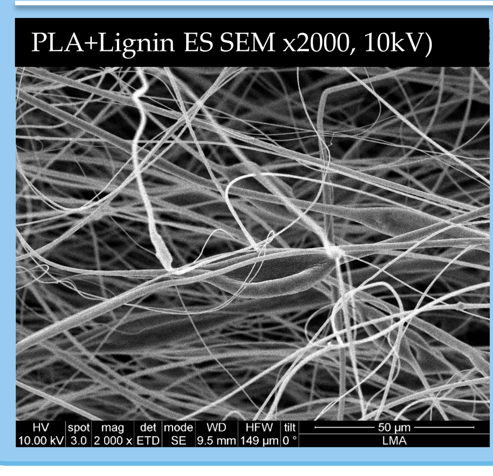
In a visible way, the more yellow points, the greater number of bacteria are.

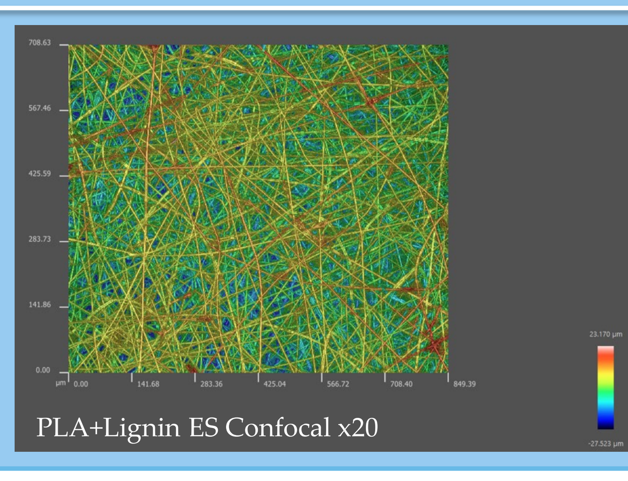
RESULTS & DISCUSSION

The SC membranes exhibited porosity, ranging from **5 to 90 micrometers** and lacking a defined geometry.
An explanation for this is solvent evaporation during fabrication. The localized loss of material may generate internal stresses that disrupt the surface, leading to pore formation.



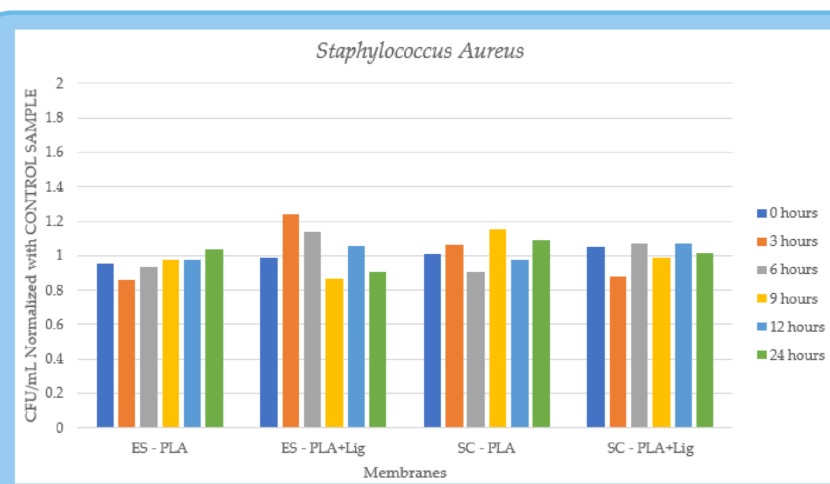


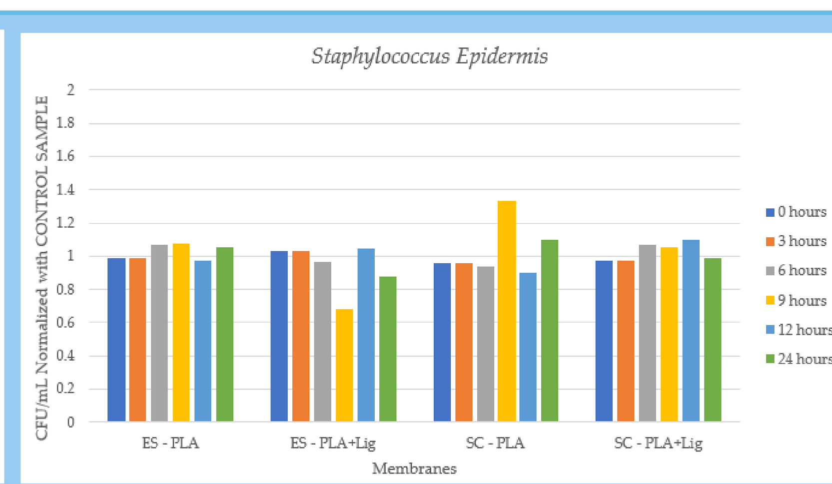


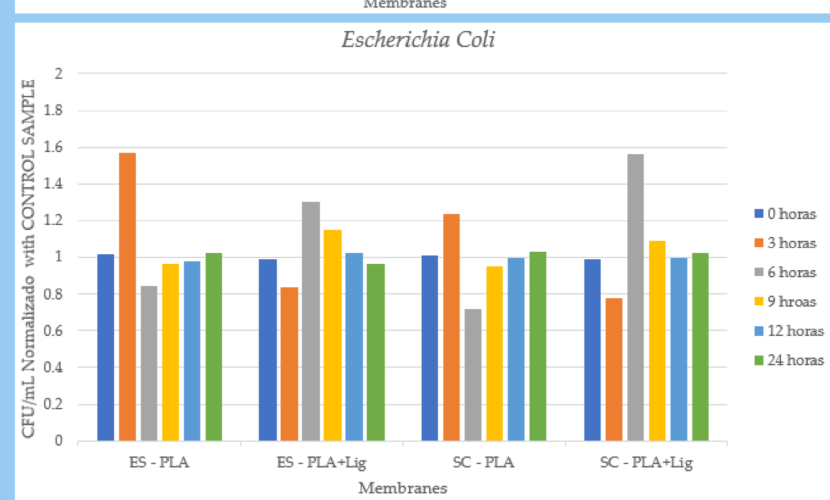


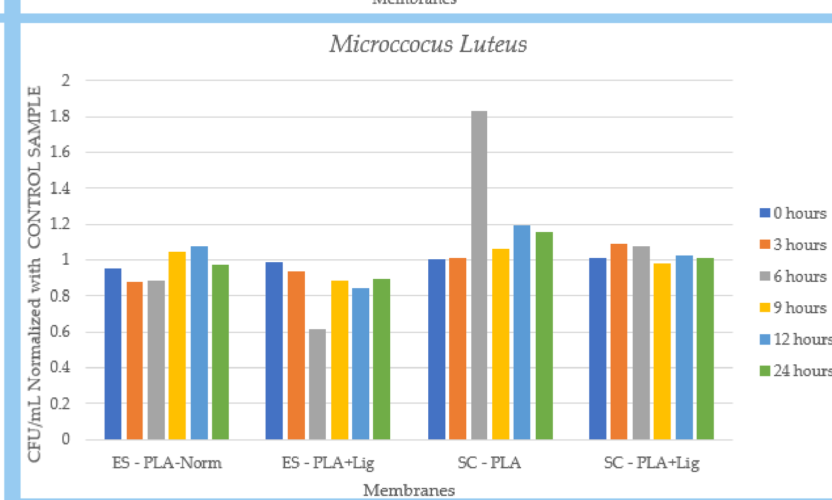
The diameters of the PLA electrospun fibers was 2.241 ± 1.329 µm and for PLA+Lignin 1.639 ± 0.754 µm.

SC membranes exhibited a thickness between 75% and 85% greater than that of ES membranes.

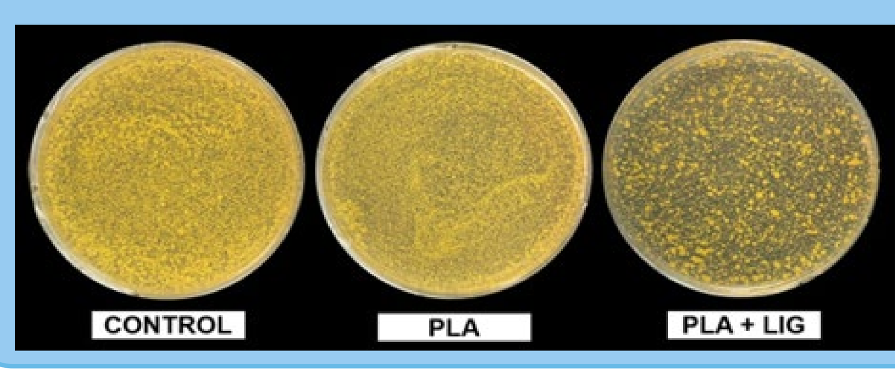








Electrospun PLA+Lignin membrane showed the lowest CFU/mL ratio against *Micrococcus Luteus*, relative to the control sample. A ratio below 1 indicates effective antimicrobial activity compared to the control.



Left) Fewer *Micrococcus Luteus* colonies (yellow dots) were observed on the electrospun PLA+Lignin membrane compared to the control and PLA-only membranes, where colonies densely covered the surface.

CONCLUSION/FUTURE WORK

- The electrospun membranes (both PLA and PLA+Lignin) were homogeneous, exhibiting a low number of defects (beads, etc.) and a fiber diameter between 1.6 to 2.2 micrometers (36% bigger in PLA than PLA+Lignine ones)
- The solution-cast membranes were also homogeneous, with some localized defects such as precursor inhomogeneities and bubble formation (solvent evaporation). These irregularities may be optimized int the future. Additionally, the solution-cast membranes presented porosity and were generally 75–85% thicker than the electrospun ones.
- The antimicrobial test results demonstrated a preliminary antimicrobial activity of the PLA+Lignin membranes against *Micrococcus Luteus*. In future studies an ANOVA analysis should be carried out to validate the findings for a more robust conclusion.

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