# Report on the outcomes of a Short-Term Scientific Mission[1]

**Action number: CA17107**

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## Details of the STSM

Title: Electrospinning of Biopolymers Solutions with Antimicrobial Agent

Start and end date: 31/05/2022 to 30/06/2022

## Description of the work carried out during the STSM

During the STSM at the Slovak Academy of Science, I produced many nanofibers enhanced with antibacterial agents. Firstly, I analyzed recent studies focused on antibacterial nanofibers and tried to find the perfect polymers for nanofiber production. As the suitable polymers for potential wound dressing because of their mechanical properties were chosen Poly (Lactic) acid (PLA, LX 175, Mw=163.000 g/mol) acid and Ecoflex F blend C1200 (Mw=24.400 g/mol). The substances with declared antibacterial properties were chosen Thymol, Eugenol, trans-Cinnamaldehyde, Carvacrol and biosurfactant Surfactin; these substances were loaded into the nanofibers in different weight concentrations.

After the analysis, I prepared countless polymer solutions appropriate for needle electrospinning. I tried many approaches, especially different solvents and concentrations, to find proper polymer solutions for electrospinning. Furthermore, I learned how to work with needle electrospinning apparatus. Until then, I had only worked with needleless electrospinning apparatus.

Moreover, produced nanofibers loaded with antibacterial agents were experimentally characterized. The nanofiber's morphology was examined by SEM (Scanning Electron Microscope). Also, the structure and composition were investigated by FTIR Spectroscopy (Fourier Transform Infrared). Besides these two methods, the nanofibers were studied by TGA (Thermogravimetric Analysis) to determine the thermal stability of nanofibers and their volatile components.

[1] This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

## Description of the STSM main achievements and planned follow-up activities

As planned, I successfully fabricated different kinds of biopolymer nanofibers loaded with an antibacterial agen (see Figure 1). These nanofibers were produced with potential use as wound dressing for small injuries. Biopolymer PLA and Ecoflex were chosen for their fabrication because of their beneficial mechanical properties.

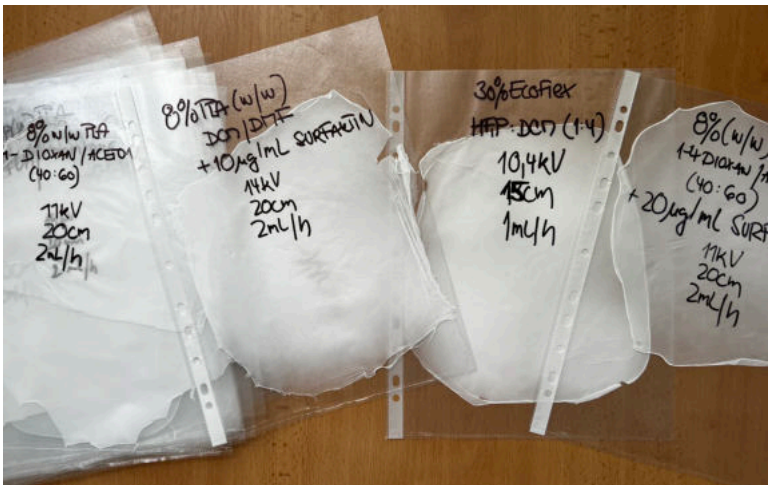


Figure 1 Fabricated nanofibers

Firstly, suitable polymer solutions were prepared for electrospinning. The PLA polymer was soluble in DCM/DMF (1:1) at a concentration of 8% w/w and also in less toxic solvents 1,4-dioxane/acetone (2:3) at a concentration of 8% w/w. The Ecoflex was soluble in HFIP/DCM (1:4) at a concentration of 30% w/w. These polymer solutions are mentioned because they were successfully spun under definite conditions. Besides pure polymer nanofibers, nanofibers with incorporated antibacterial properties in concentrations of 2%, 4%, and 6% w/w were also produced as well as their combinations. All spun nanofibers can be seen in Table.

Table Produced nanofibers layers

| | Polymer | Solvent | Antibacterial agent | Electrospinning parameters |
|---|---|---|---|---|
| 1 | 8% w/w PLA | DMF/DCM | x | flow rate: 2 mL/h, voltage: 14 kV, collector distance: 18 cm |
| 2 | 8% w/w PLA | DMF/DCM | 10 µg/mL Surfactin | |
| 3 | 8% w/w PLA | DMF/DCM | 15 µg/mL Surfactin | |
| 4 | 8% w/w PLA | DMF/DCM | 20 µg/mL Surfactin | |
| 5 | 8% w/w PLA | DMF/DCM | 25 µg/mL Surfactin | |
| 6 | 8% w/w PLA | DMF/DCM | 2% w/w Eugenol | |
| 7 | 8% w/w PLA | DMF/DCM | 4% w/w Eugenol | |
| 8 | 8% w/w PLA | DMF/DCM | 6% w/w Eugenol | |
| 9 | 8% w/w PLA | DMF/DCM | 2% w/w Thymol | |

| | | | | |
|---|---|---|---|---|
| 10 | 8% w/w PLA | DMF/DCM | 4% w/w Thymol | |
| 11 | 8% w/w PLA | DMF/DCM | 6% w/w Thymol | |
| 12 | 8% w/w PLA | DMF/DCM | 2% w/w trans-Cinnamaldehyd | |
| 13 | 8% w/w PLA | DMF/DCM | 4% w/w trans-Cinnamaldehyd | |
| 14 | 8% w/w PLA | DMF/DCM | 6% w/w trans-Cinnamaldehyd | |
| 15 | 8% w/w PLA | DMF/DCM | 2% w/w Carvacrol | |
| 16 | 8% w/w PLA | DMF/DCM | 4% w/w Carvacrol | |
| 17 | 8% w/w PLA | DMF/DCM | 6% w/w Carvacrol | |
| 18 | 8% w/w PLA | DMF/DCM | 1% Thymol + 1% Eugenol (w/w) | |
| 19 | 8% w/w PLA | DMF/DCM | 2% Thymol + 2% Eugenol (w/w) | |
| 20 | 8% w/w PLA | DMF/DCM | 1% Carvacrol+ 1% trans-Cinnamaldehyd (w/w) | |
| 21 | 8% w/w PLA | DMF/DCM | 2% Carvacrol+ 2% trans-Cinnamaldehyd (w/w) | |
| 22 | 8% w/w PLA | 1,4-dioxane/acetone (2:3) | x | flow rate: 2 mL/h, voltage: 11 kV, collector distance: 20 cm |
| 23 | 8% w/w PLA | 1,4-dioxane/acetone (2:3) | 10 µg/mL Surfactin | |
| 24 | 8% w/w PLA | 1,4-dioxane/acetone (2:3) | 15 µg/mL Surfactin | |
| 25 | 8% w/w PLA | 1,4-dioxane/acetone (2:3) | 20 µg/mL Surfactin | |
| 26 | 8% w/w PLA | 1,4-dioxane/acetone (2:3) | 25 µg/mL Surfactin | |
| 27 | 30% w/w Ecoflex | HFIP/DCM (1:4) | x | flow rate: 1,5 mL/h, voltage: 10,5 kV, collector distance: 19 cm |
| 28 | 30% w/w Ecoflex | HFIP/DCM (1:4) | 10 µg/mL Surfactin | |
| 29 | 30% w/w Ecoflex | HFIP/DCM (1:4) | 15 µg/mL Surfactin | |
| 30 | 30% w/w Ecoflex | HFIP/DCM (1:4) | 20 µg/mL Surfactin | |
| 31 | 30% w/w Ecoflex | HFIP/DCM (1:4) | 25 µg/mL Surfactin | |

Furthermore, these nanofibers were examined by FTIR to observe the composition of the final products and to consider any changes in the IR spectrum with loaded antibacterial agents. Because we used a very low antibacterial agent concentration, no changes could be seen in the IR spectrum except the Eugenol.

The surface morphology by SEM was also investigated, and the nanofibers' diameters are going to be determined. It can be observed a significant difference between PLA nanofibers produced from solution DCM/DMF and less toxic 1,4-dioxane/acetone (see Figure 2). Nanofibers spun from less toxic solvents have more defects than from the other solvents. Also, it can be seen more beads on nanofibers with incorporated antibacterial agents (see Figure 3).

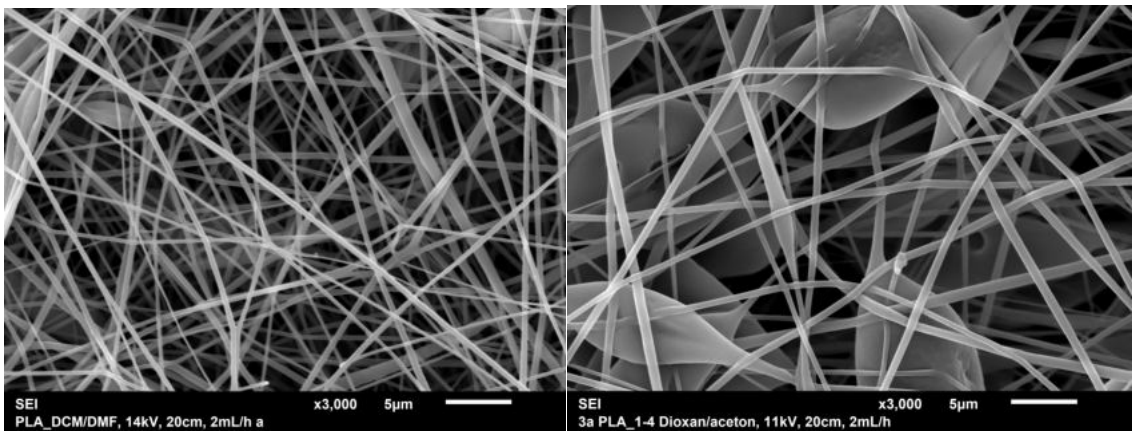


Figure 2 SEM characterization of PLA fabricated from different solutions

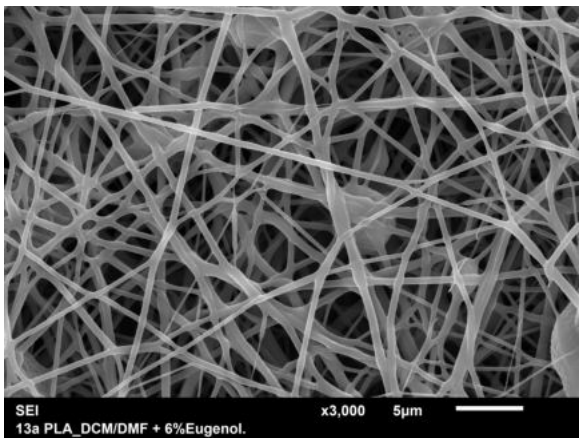


Figure 3 SEM characterization of PLA/(DCM/DMF) nanofibers with incorporated Eugenol

Moreover, other characterizations are going to be tested at Tomas Bata University in Zlin, such as polymer solutions characterizations (viscosity, surface tension, electrical conductivity), mechanical properties (tensile tension), thermomechanical properties (DSC), the contact angle analysis, the release test, antimicrobial and antifouling activity and their biodegradability.

Observation of nanofibers' biocompatibility has been planned in the Slovak Academy of Sciences later this month.

As a resulting outcome of STSM, two articles at least will be written and hopefully successfully published in journals.