Electrospinning and Potential Application in Biomedical Technologies

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Background

Research Goal

By using nanofiber and nanoribbon materials synthesized using electrospinning, we create a scaffold of the likes of the **extracellular matrix (ECM)**. These scaffolds have the potential to be applied in regenerative medicines and other biomedical technologies. The fiber networks which cells bind to and grow on, allow for the creation of 3D tissue networks.

What electrospinning does

Mixtures of varying concentrations of **dextran** (a branched polymer of dextrose) and deionized water were formed into scaffolding using **electrospinning,** resulting in nanofibers of differing cross-sectional widths, patterns, and concentrations. By varying the concentrations and the ratio of solute to solvent, as well as the distance of our apparatus from the collecting plate, we discovered that **we could control the structure between fiber-like and ribbon-like structures.**

Applications

Regenerative medicine

For **tissue engineering, bone regeneration, and cartilage regeneration** electrospinning are combined with biocompatible materials to form polymeric scaffolds. For example, collagen fibrils are aligned parallel to the articular surface and superficial zone which are also oriented perpendicular to the articular surface in the middle and deep zones. [2]

Cancer diagnosis

Biosensors incorporated into electro-spun fibers can be used for **early cancer diagnosis**. Antibodies, functional groups, and oxygen sensitive materials can be incorporated into the nanofibers. Combination between electro-spun nanofibers with microfluidic techniques can improve the diagnostics sensitivity. [2]

Stem Cell Delivery

Ribbon hydrogels have been shown to be highly desirable for applications in stem cell delivery which can be used for bone regeneration in vivo. It was shown that these structures enhanced and accelerated bone formation via injectable and crosslinkable gelatin microribbons. [3]

Research Objectives

Electro-spun dextran-based nanofibers to analyze optimal conditions for potential biomedical applications by performing the following:

- Form solutions
- Electrospin nanofibers
- Analyze and characterize nanofibers

Methods

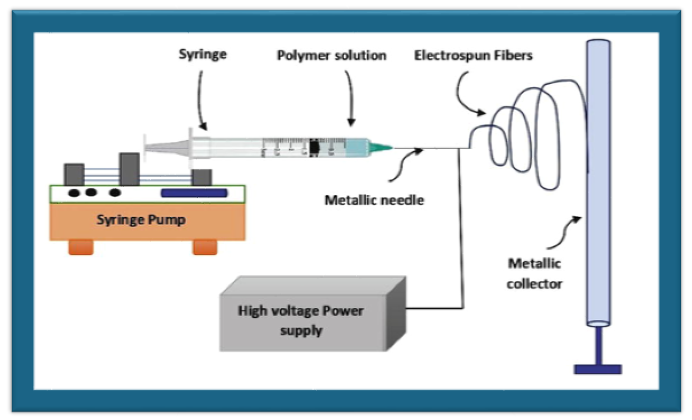

Fig.1: Diagram of electrospinning machine and strands [1]

Fig.2: electrospinning machine

Process of Electrospinning

When electrospinning fibers, polymer solutions are spun into nanofibers using the machine shown in figure 1. The syringe's plunger is pushed in at a very slow rate and the solution is extruded from the needle's tip. High voltage is applied to the needle which charges the stream of solution which results in the creation of strands that are collected on a conductive plate.

Materials

Materials Needed For Spinning

- Dextran
- Deionized Water (DIW)
- Syringe
- Electrospinning pump
- High Voltage power source
- Conductive collection plate

How Solutions were Made

Dextran with molecular varying between 60k and 450k were mixed in both 20% and 50% solute to solvent ratios. The solvent used was DIW.

Why Dextran was Used

Dextran was best suited for the purpose of electrospinning with the intent of biomedical applications because it is a naturally occurring polysaccharide (sugar) rather than a synthetic one.

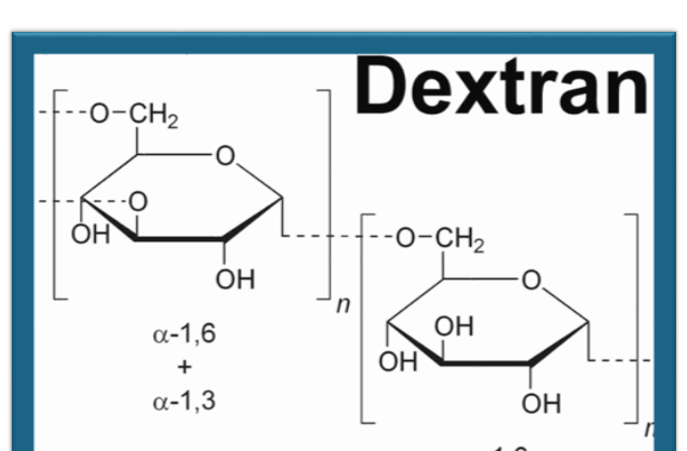

Fig 9: Structure of dextran molecule

Characterization

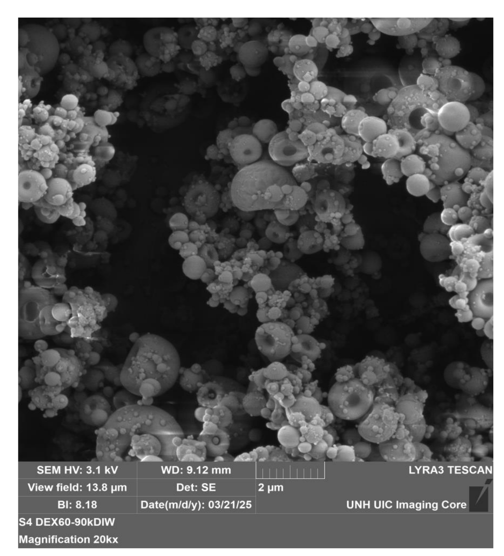

Fig.3: 20% Dex 60-90k + DIW

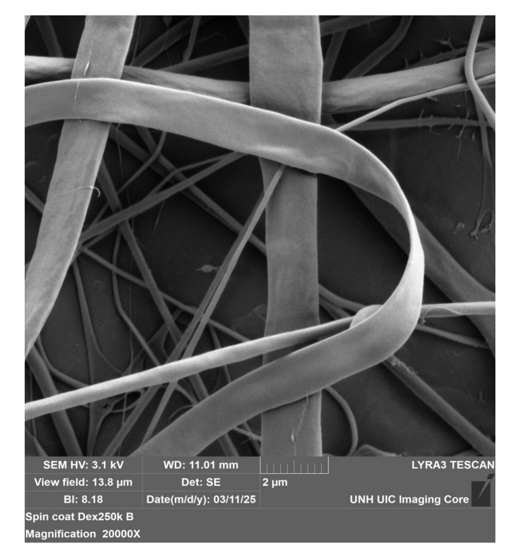

Fig.4: 20% Dex 250k + DIW

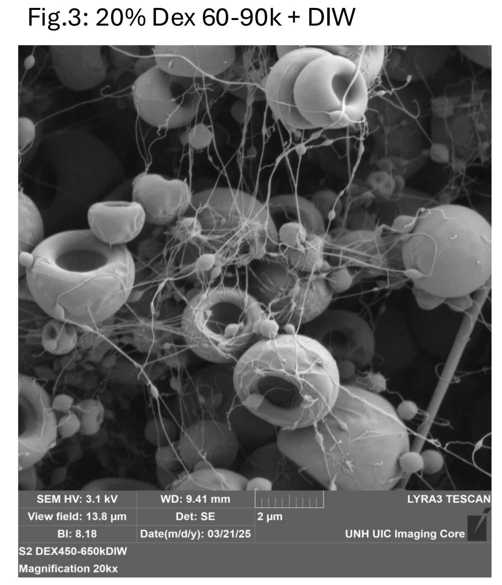

Fig.5: 20% Dex 450k + DIW

Observing the 20% dextran solutions in an SEM microscope revealed that we had formed **ribbon structures** opposed to the expected fiber-like structures typical of dextran electrospinning.

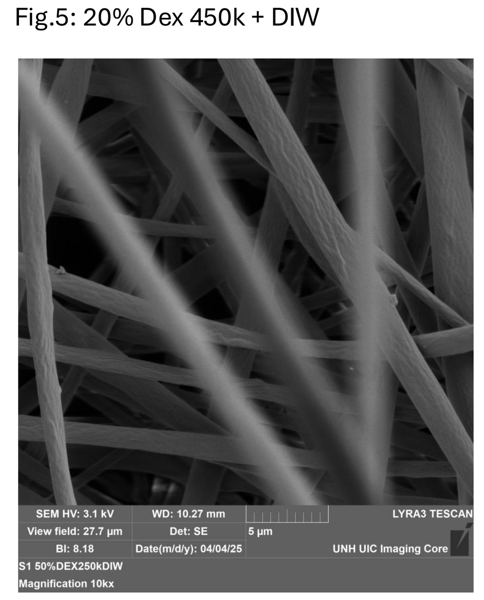

Fig.6: 50% Dex 250k + DIW (10kx magnified)

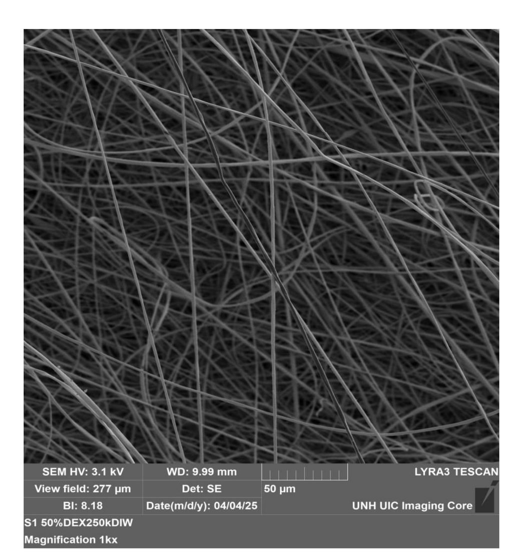

Fig.6: 50% Dex 250k + DIW (1000x magnified)

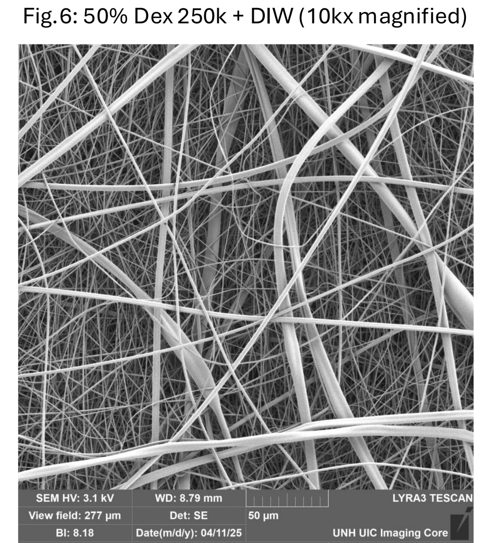

Fig.8: 50% Dex 60-90k + DIW

Whereas the 50% solution produced the expected **fiber structures**. We also observed the 50% dextran solutions to be more consistent in forming fibers.

Solution	Distance (cm)	Formed Fibers	Formed Ribbons
20%DEX60-90k+DIW (fig. 3)	10	X	X
20%DEX250k+DIW (fig. 4)	21	X	✓
20%DEX450k+DIW (fig. 5)	21	X	X
50%DEX60-90k+DIW (fig. 6)	15	✓	X
50%DEX250k+DIW (fig. 7)	15	✓	X

Table 1: Experiment parameters and which structures were formed

Observations

Across both solutions, the 250k solutions most consistently formed the best and most uniform fibers/ribbons. Further research is required for us to fully determine why the different concentrations produced different structures, however with this knowledge we could consistently produce one or the other for use in their respective applications. This would allow us to efficiently create the materials we need for the processes listed in the applications section.

Conclusions

After analyzing our electrospun fibers under a scanning electron microscope, it was found that a 50% percent ratio of dextran to DIW was able to produce the best fibers. Even further, dextran with a molecular weight of 250k produced the most uniform fibers. Fibers also formed best when the syringe was placed 15 cm from the collection plate. While most of the 20% was unsuccessful at making fibrous structures, it was found that the 250k molecular weight was able to form ribbon like structures. The ribbons seemed to only form at a lower concentration of Dextran and formed best using 250k dextran. While it may take more tests to perfect how to form these ribbons, If a way to consistently form ribbons while spinning can be found then they could potentially be applied to biomedical technology in different ways. If changes in the parameters used can decide whether ribbons or fibers are formed, then maybe further experimentation with parameters can lead to even more kinds of structures forming.

References

Authors (first and middle abbreviated), journal title, article title, journal publishing year, journal edition, page numbers

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