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Estimating glucose diffusivities by experiments and image processing and spreading performance in electrospun fibers for bone tissue engineering

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Introduction and Aim

Electrospinning is a common technique for scaffold fabrication for tissue engineering bioreactors. A thorough understanding on the effects of key parameters on nutrient transport in the scaffold is substantial for fabricating scaffolds with desired morphology. To address these issues partially, we prepare electro-spun polycaprolactone (PCL) scaffolds with different pore morphology by using different electrospinning duration and polymer solution flow rate. The glucose diffusivities of scaffolds imbibed in cell culture medium (CCM) and water are also investigated experimentally and by image processing. In addition, we also study the relationship between scaffold morphology characteristics and spreading behavior.

Materials and Methods

1) Materials
   - Three pre-made PCL electrospun scaffolds
   - Cell culture medium (CCM)

2) Diffusion experiments

A diffusion cell was built to determine the glucose diffusivities in CCM. The PCL scaffold is fixed in between. Samples are taken from both donor and receptor phase every hour until equilibrium is achieved. The glucose concentration is measured by YSI glucose analyser. The glucose diffusivity is calculated by the equation 1.

\[ D = \frac{1}{\beta t} \ln \left( \frac{C_{i,glucose-CCM \times water}}{C_{f,glucose-CCM \times water}} \right) \]

- \( D \): effective diffusion coefficient of glucose
- \( t \): diffusion time.
- \( C \): the concentration of glucose and i and f denote the initial and final, respectively.
- \( \beta \): calculated by dividing the slope of the line with the diffusion coefficient of ethanol in water.

3) Water and CCM spreading experiments on dry and pre-wetted scaffolds

Both dry and pre-wetted scaffolds are employed in this study. The temperature is 20±1 °C and humidity is 48±2%. KRUSS DSA100 drop shape analyzer (figure 1) is used to monitor the water and CCM spreading process on PCL scaffold surface. When measurement is about to start, 10μL water/CCM drop is placed on the scaffold surface by pipette. During the experiments, the image is transferred to a computer equipped with DSA4 software, which contains time-proven tools for analyzing the drop image with whose help it is possible to calculate the contact angle.

Results discussion

The diffusivities in CCM through these 3 scaffolds are shown in table 2, which increases with increasing fiber-fiber space, indicating less resistance of glucose molecules diffusing through the pores. Data also showed a significant reduction of glucose diffusion coefficient through materials saturated with CCM. The results from image processing are close to the experimentally obtained results. Hence, it is possible to predict the diffusion coefficients through this method.

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Effective diffusivities in CCM ( \times 10^8 \text{m}^2/\text{s} )</th>
<th>Effective diffusivities in water ( \times 10^8 \text{m}^2/\text{s} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.83±0.120</td>
<td>6.31±0.313</td>
</tr>
<tr>
<td>2</td>
<td>1.75±0.268</td>
<td>8.27±0.229</td>
</tr>
<tr>
<td>3</td>
<td>3.22±0.107</td>
<td>7.38±0.273</td>
</tr>
</tbody>
</table>

In experimental work, effective diffusion coefficients of glucose in both water and CCM are obtained. As the pore size increases, the diffusivity increases. The diffusion coefficients in CCM are smaller than those of in water. The results are comparable to simulated values by SEM image processing. Meanwhile, it is observed that electrospun PCL scaffolds permits low wettability and that increasing fiber-fiber space of scaffolds leads to decreasing static contact angle. Furthermore, it takes longer to achieve balance with CCM drops and therefore decreasing the wettability performance. It is also shown that pre-wetted scaffold has better wettability and lower surface tension between wet surface and water/CCM drop.

Reference: