



Porous scaffolds based on poly(L-lysine)/microcrystalline cellulose biocomposite

Mohamed Farag Eldessouki, Gisela Buschle-Diller, and Yasser Gowayed

The unique features of poly(L-lysine) and microcrystalline cellulose combine to produce a more stable material for tissue-engineering scaffolds.

Growing research in the field of regenerative medicine focuses on finding alternative ways to restore, maintain, or enhance damaged or diseased organs. Scaffold formation is one of the key elements for regenerative medicine where a bioresorbable material is implanted in the body to form a 3D template for cell adhesion. Scaffolds also provide the temporary mechanical support needed during cell growth. A promising candidate for a scaffold material is poly(L-lysine) (PLL), which is a biocompatible polymer whose lysine repeat units are essential building blocks of proteins in organisms. Although PLL has potential advantages for tissue-engineering materials, due to its relatively weak structure and hydrophilicity, its application has been limited to surface property enhancements of scaffolds made from other polymers. Attempts have been carried out to counteract its poor mechanical properties by reinforcing PLL with nanoclays,¹ carbon nanotubes,² and bioceramic particles of hydroxyapatite.³

Our research⁴ focuses on the possibility of reducing the hydrophilicity of PLL and creating a tissue-engineered scaffold with reasonable swelling capabilities by incorporating microcrystalline cellulose (MCC) particles. Although osteoconductive (guiding the growth of natural bone), cellulose by itself does not stimulate cell growth and would need a compound such as PLL to synergistically recruit cells while keeping the scaffold sufficiently stable. The presented work focuses on the effect of processing conditions on both MCC and PLL, such as the effect of pH on the polypeptide and of hydrolysis on the crystallinity level of the cellulose. We also varied the MCC content to study its correlation with the properties of the scaffold. The porous scaffold samples (see Figure 1 for an example) were produced through the thermally induced phase separation method.

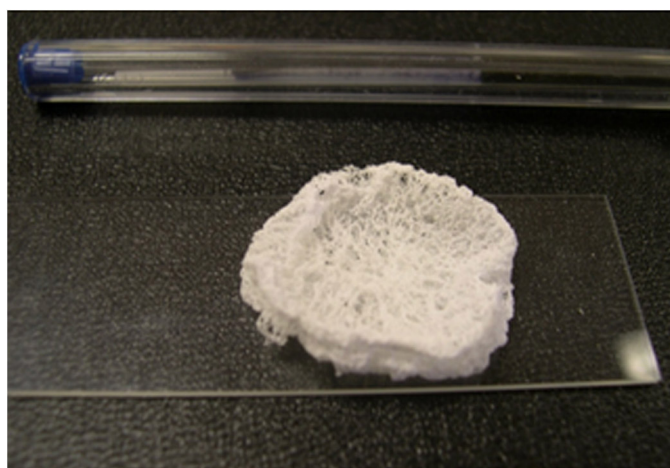


Figure 1. Disc-shaped poly(L-lysine) microcrystalline cellulose scaffold sample.

Our results⁴ show a formation of an intimate composite structure with attractive electrostatic forces between the two components of the material. We also found that the processing of the polypeptide is important in determining its final secondary structure. The commercially obtained PLL existed in the α -helix secondary structure, and remained in this conformation when dissolved in solutions of pH levels higher than its pK_a value. At neutral pH and in solutions below its pK_a , however, the polymer assumed a β -sheet conformation. At pH 7, the polymer may be protonated and some cationic charges might develop on the polymer chain, generating electrostatic repulsive forces. These forces can result in the breaking of the intrachain hydrogen bonds of the α -helix, favoring the transformation to a β -sheet structure in order to minimize the conformational energy of the polypeptide.

The hydrolysis methods applied (both with and without sonication) resulted in about a 25% increase in the crystallinity of the cellulose particles. When sonication was applied during the hydrolysis process, the

Continued on next page



resulting particles were relatively well dispersed and fairly small, while without sonication the average particle size was larger (even larger than the original MCC particles). It is possible that without sonication, aggregates formed and resulted in an increase in the measured particle size. For the scaffolds produced, we measured the density, volumetric porosity, and the swelling percentage and studied the impact of processing parameters. An increase in the volumetric porosity resulted in a decrease of the structure density, while the increase in crystallinity led to an increase in density of the scaffold and a decrease in the swelling of the sample.

Biocompatible materials with good physical properties are important for designing tissue-engineered scaffolds. Our research has showed that increasing the crystallinity of the semi-crystalline PLL (after its formation in a biocomposite with microcrystalline cellulose) can increase its physical integrity in aqueous media and prevent its dissolution. In the future, this work can be expanded to study the mechanical properties of the scaffolds produced using such porous structure techniques as cellular solids modeling and analysis.

Author Information

Mohamed Farag Eldessouki

Mansoura University
Mansoura, Egypt

Mohamed Farag Eldessouki is currently an assistant professor at Mansoura University. His main research interest is the study and development of polymeric biomaterials.

Gisela Buschle-Diller and Yasser Gowayed

Department of Polymer and Fiber Engineering
Auburn University
Auburn, AL

References

1. T. Sawai, S. Yamazaki, Y. Ishigami, Y. Ikariyama, and M. Aizawa, *Rapid redispersion of pH-sensitive microgel flocculation with poly(lysine)*, **Macromolecules** **24**, pp. 5801–5805, 1991. doi:10.1021/ma00021a012
2. Y. Zhang, J. Li, Y. Shen, M. Wang, and J. Li, *Poly-L-lysine functionalization of single-walled carbon nanotubes*, **J. Phys. Chem. B** **108**, pp. 15343–15346, 2004. doi:10.1021/jp0471094
3. Y. Ding, J. Liu, X. Jin, H. Lu, G. Shen, and R. Yu, *Poly-L-lysine/hydroxyapatite/carbon nanotube hybrid nanocomposite applied for piezoelectric immunoassay of carbohydrate antigen 19-9*, **Analyst** **133**, pp. 184–190, 2008. doi:10.1039/B713824E
4. M. Eldessouki, G. Buschle-Diller, and Y. Gowayed, *Poly(L-lysine)/microcrystalline cellulose biocomposites for porous scaffolds*, **Polym. Compos.** **32**, pp. 1937–1944, 2011. doi:10.1002/pc.21220