Spider Silk-Hydrogels, Lyogels, Sponges

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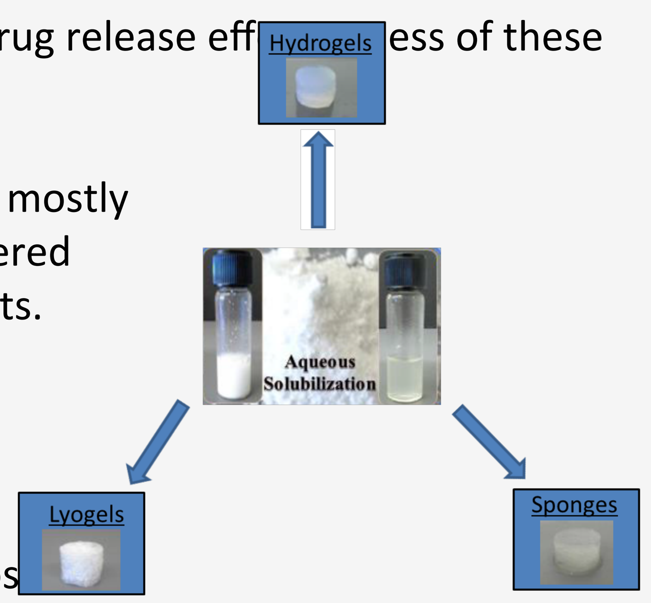
Introduction

Spider silk is stronger than Kevlar and more elastic than nylon. These characteristics have led scientists to attempt mass production and world renowned research of the strongest fiber on earth and one of the strongest materials known to man. Only recently has spider silk been artificially produced in large enough quantities to branch out to its endless possibilities. Utah State University's USTAR program has used transgenic goats to produce spider silk protein within their milk. Once these proteins are extracted from the goat's milk it can be restructured in to fibers, adhesives, hydrogels, and coatings.

Spider silk has opened the potential for aqueous based protein materials. Spider silk has been dissolved in aqueous solutions and hydrogels, lyogels, and sponges have been produced. With an aqueous based solution we have determined each of these materials to be biocompatible through immortalized cell culture. This opens a broad range of biomedical uses for each of these materials. We determined the mechanical strength, structural stability, diffusion rate, and drug release effectiveness of these materials.



Hydrogels are a gelatinous material composed of mostly water. Their molecular rearrangement can be altered with the incorporation of different post treatments.

Sponges are the result of hydrogels that have been frozen in water then allowed to thaw.

Lyogels are lyophilized hydrogels that are composed of mostly air and spider silk protein.

The properties of the hydrogels, lyogels, and sponges have been characterized by mechanical testing, FTIR, UV spectrometry, and SEM. Through testing and exploration, hydrogels have been loaded with antibiotics and much has been learned about the rates of drug release and diffusion through the gels. Although the research on sponges is very new, great strides have been made in showing that they have potential in the biomedical industry especially with their ability to be completely dehydrated then rehydrated again. These different materials can potentially be applied to many different healing applications. The structure and capability of hydrogels, lyogels, and sponges to withstand compression have been studied for all materials. Though each material is related and similar they all have vastly different mechanical properties that give each material distinct properties and capabilities to achieve different tasks.

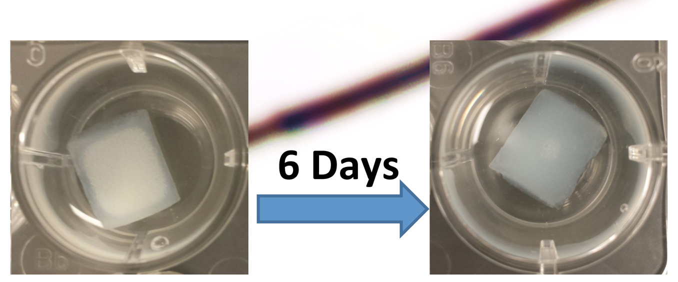


Figure 1. Visual of dexamethasone release from hydrogel.

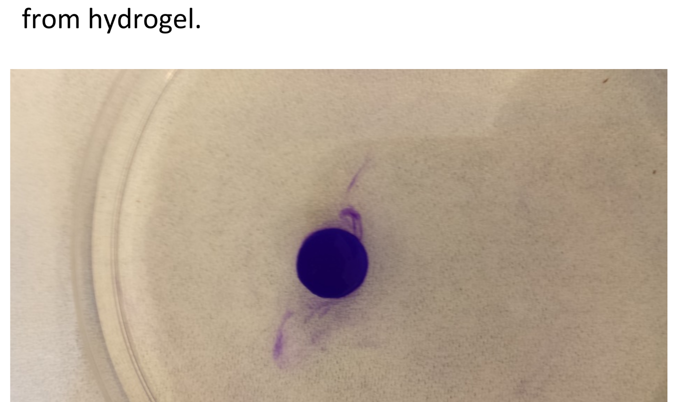


Figure 2. Initial methyl violet release from hydrogel in PBS.

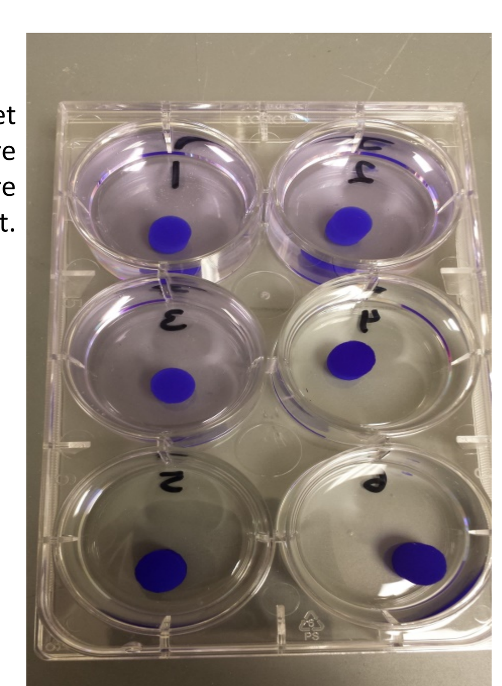
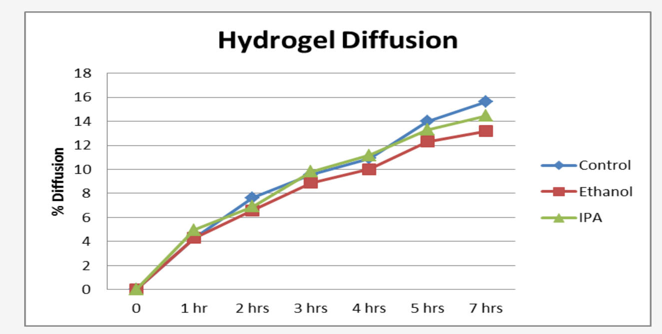
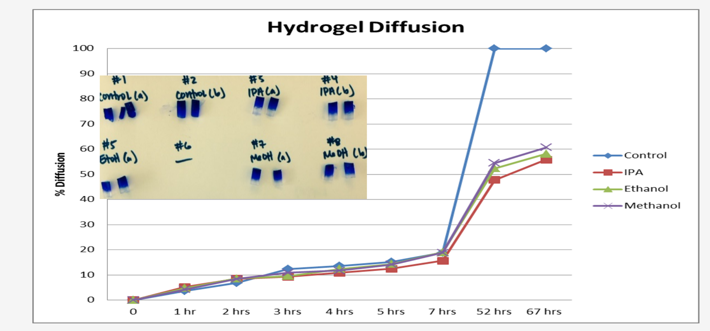


Figure 3. Hydrogel methyl violet release study. Wells 1,2,3 were post treated. Wells 4,5,6 were loaded with methyl violet.

Results

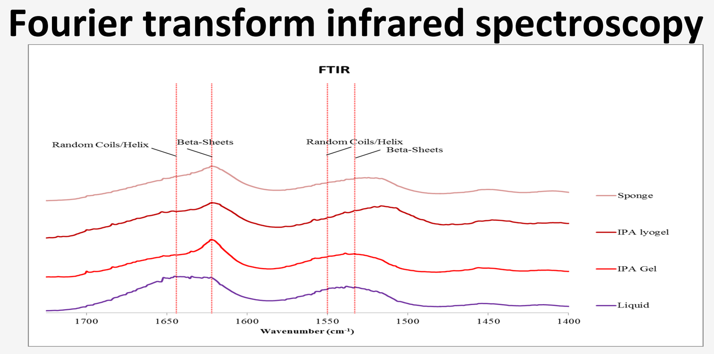
Diffusion:





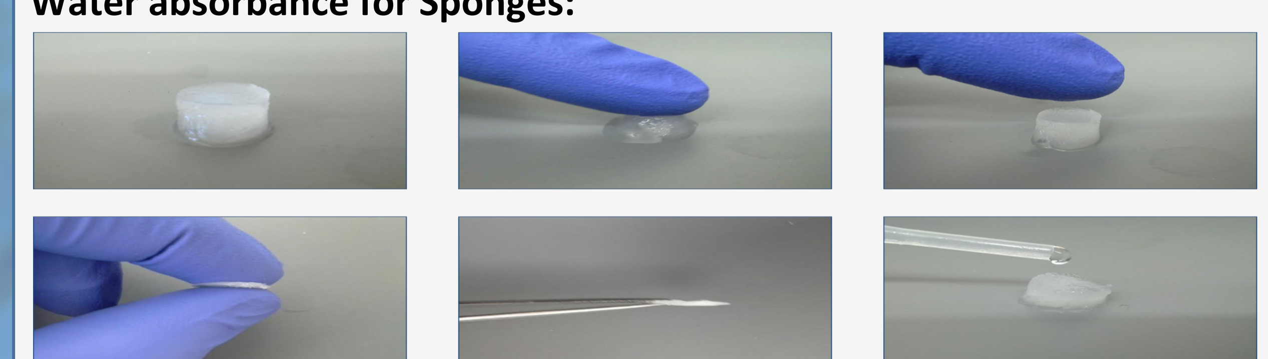
Diffusion rates for hydrogels treated with different post treatments (Ethanol, IPA, and Methanol).

Fourier transform infrared spectroscopy (FTIR):



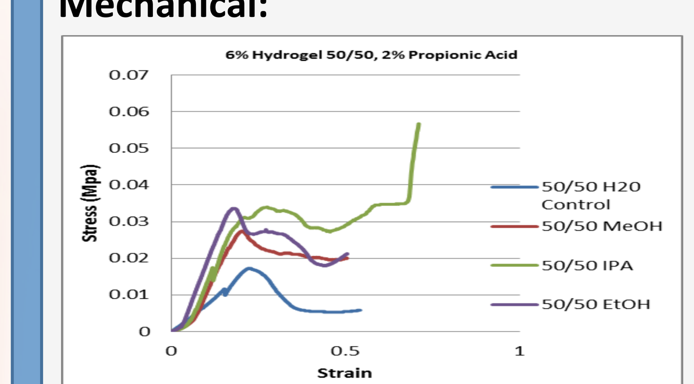
The structure of hydrogels, lyogels, and sponges can be explained by the secondary structures of the materials. β- sheet structures are shown by the distinct peaks.

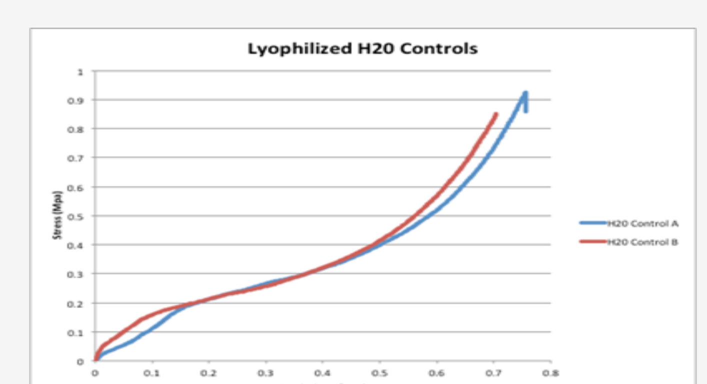
Water absorbance for Sponges:



Sponges have the ability to be compressed flat and dehydrated. After being loaded with water rehydrated sponge can recover to original shape and size.

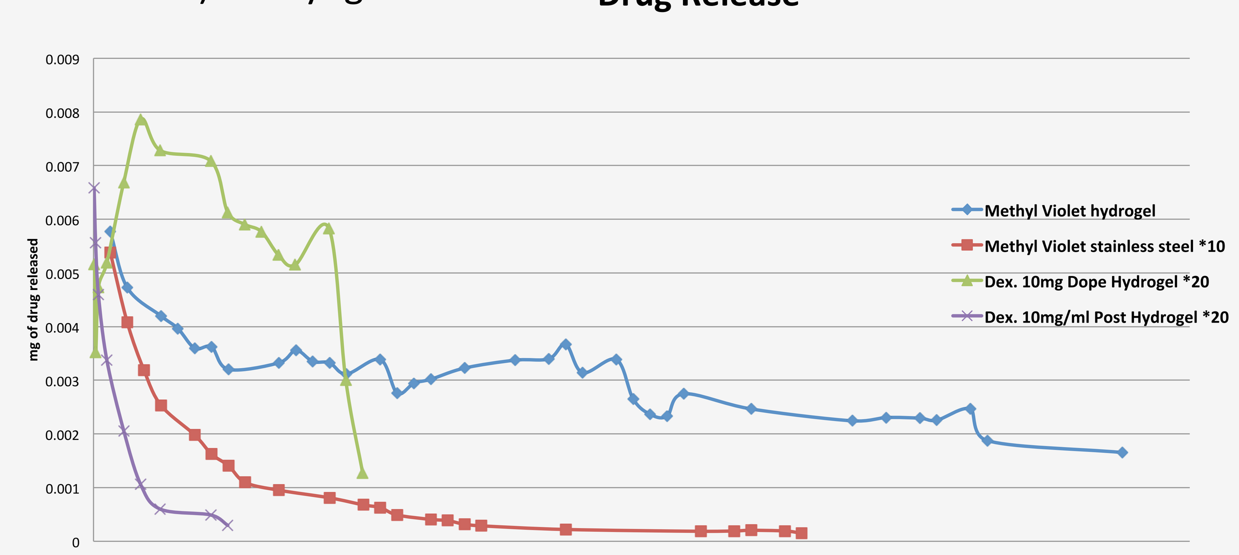
Mechanical:





Compression test results for hydrogels (treated with different post treatments) and lyogels.

Drug Release



Spider silk materials loaded with different drugs were studied over time to understand their releasing properties.

Conclusions

Spider silk, once known as the biomaterial of the future, is quickly becoming the biomaterial of today. The hydrogels, lyogels, and sponges have undergone initial tests to prove the future possibilities of these materials. Each material has substantial potential. From our results we have found that the hydrogels can be loaded with drugs that can be steadily released over time. Our results indicate that these materials can withstand various biological environments and can be utilized in many different biomedical applications.

Future Work

Gels are a novel material that have been loosely explored but through research have shown to have a great deal of potential in the biomedical industry.

There is a great demand for drug release of biological active compounds that can positively affect the healing and application process. Gels loaded with stem cells, growth factors, or morphogenic proteins may be used in tissue, bone, and neural repair. We will be working on matching the drugs to specific needs and applications as well as diversified materials to achieve successful application. Once we have achieved successful laboratory results we will begin *in vivo* research.

Although gelation time is reasonable for hydrogels, more research is needed to control the rate of gelation.

Sponges have vast potential that requires further research.

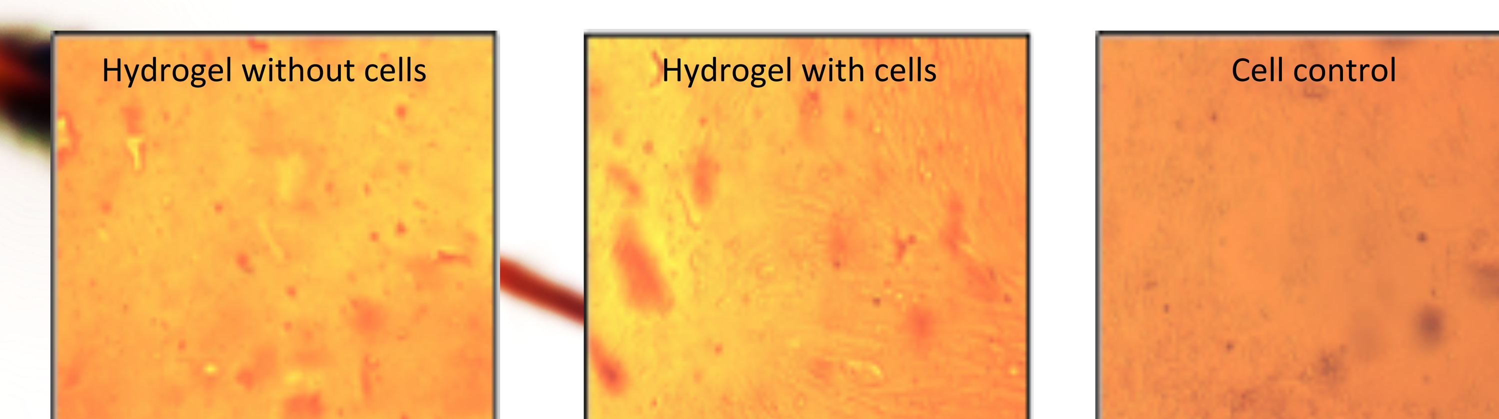


Figure 4. Hydrogels were seeded with Chinese Hamster Ovary (CHO) cells and allowed to grow for 4-6 days before taking images with a light microscope. Cells growing within the hydrogel demonstrates the biocompatibility of the hydrogels.

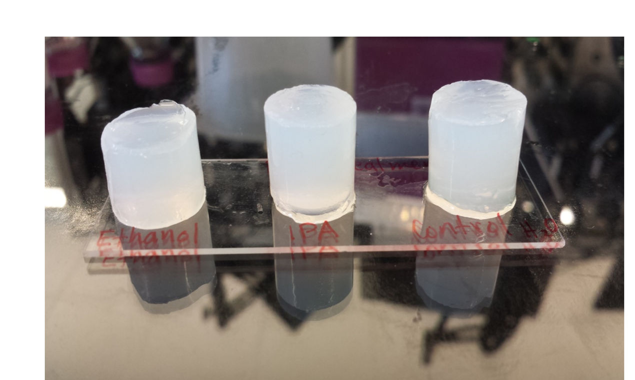


Figure 5. Different post treated hydrogels.