Introduction: In this particular study special attention is being given to cellulose, and more specifically cellulose that is produced by the bacteria *acetobacter xylinum*. Polymer composites are becoming increasingly more important in many different applications because of their light weight and superior mechanical properties (Seavey and Glasser 2001, p.149). Seavey and Glasser have been doing research on polymer composites that are comprised of Lyocell fibers which are spun from solutions of cellulose biomass using the solvent N-methyl morpholine-N-oxide and cellulose acetate butyrate as the matrix. They have reported making composites that have a tensile strength of 300 MPa and modulus of 20.0 GPa (Seavey and Glasser 2001, p.178).

Cellulose is a series of repeating glucose units which are linked together by beta-1, 4 linkages:

These cellulose chains interact with each other to form microfibrils which are 2-20 nm in diameter and can be up to many microns in length. Part of the reason that we are focusing our attention on bacterial cellulose is that currently the cellulose being used to make composites is processed from wood pulp and while undergoing this isolation the strength of the cellulose is reduced. Also, cellulose produced from bacteria is a potentially renewable source that will allow industry to be less dependent on the wood industry. Most intriguing, however, is the ability of this particular strain of bacteria to produce chains of cellulose in an antiparallel conformation which is more thermodynamically stable than the cellulose that is processed from wood pulp.

Overall Goal: Dr. Laborie is trying to set up a new course for study for the graduate course in composites that deals primarily with the study of 100% cellulose composites. That is, a composite that uses bacterial cellulose fibers as the reinforcement and cellulose esters as the matrix. This is a brand new project with few concrete goals to start off with, so the research to begin with will be limited to resources and facilities at hand with the constraints on time.

Summer Research: The majority of the summer was spent in using a strain of *acetobacter xylinum* to produce cellulose that could be harvested and used in the process of creating a composite with cellulose acetate butyrate, as well as probe the feasibility of various types of composite casting. These are just preliminary tests, designed at getting a feel for this area of research and establishing a direction for further research.

Bacterial Cellulose: The cellulose producing strain *acetobacter xylinum* was purchased from ATCC, number 53582. Schramm and Hestrin broths was used to nourish the bacterial strain as recommended by various researchers that are focusing on microbial cellulose such as Dr. A. K. Mohanty and Dr. Malcolm Brown Jr. The bacteria synthesizes layers of cellulose on the surface from the glucose present within the broth. Cellulose yields obtained were between 15 – 25% by weight in comparison to the initial amount of glucose within the Schramm and Hestrin broth. Dr. Malcolm Brown Jr. has reported yields that slightly exceed 35% using polyethylene coverings to allow a higher amount of oxygen to interact with the surface of the nutrient media (Brown). Cellulose pellicles were washed by boiling in 0.5 M NaOH, rinsing, soaking in bleach, rinsing, soaking in distilled water, and then air drying. Cellulose once dry had a consistency very similar to that of paper and was slightly brittle. Samples of the cellulose harvested were analyzed under SEM (Scanning Electron Microscope), TEM (Transmission Electron Microscope), and in the DSC (Differential Scanning Calorimeter).

Casting of the composite: Ideally, long-chain cellulose esters would have been ideal to form composites with, because then their melting temperature would be low enough that a plasticizer would not be needed to lower the melting temperature below that of the degradation point of the cellulose fibers. Unfortunately, there are no commercially manufactured long-chain cellulose esters, and with our budget we could not afford them anyway.

Samples of cellulose acetate butyrate (CAB-381-20) were obtained from Eastman Chemical Company. In case a plasticizer was going to be needed a sample of triethyl citrate was generously provided by Moreflex, chosen based on the research done by Dr. A.K. Mohanty (Mohanty 2004).

Solvent Casting was tried first, using DMA/LiCl as the solvent for the cellulose and CAB. Thermodynamically the two constituents would not come together to form a composite on their own. Other types of casting would need a plasticizer to bring the melting temperature of the CAB down in order to prevent the cellulose fibers from degrading.

The first DSC graph shows that the melting temperature of the CAB alone is at 166 degrees Celsius and on the DSC graph in the middle column of the cellulose fibers it can be seen that they begin to degrade at 150 degrees Celsius. The second DSC curve is that with 30% plasticizer in it, and it can be seen that the melting temperature actually goes way up instead of going below the degradation threshold of the cellulose.

Conclusions:
- Bacterial cellulose fibers and CAB do not interface well thermodynamically, which may be caused by the CAB having too high a degree of substitution.
- Triethyl citrate is not an adequate plasticizer for CAB.
- The bacterial cellulose harvested when analyzed under the SEM and TEM showed signs of crystallinity.

Future Considerations:
- Investigate CAB as to whether or not the degree of substitution can be reduced so that a cellulose composite could be solvent cast, cutting back on amount of cellulose needed.
- Find a better plasticizer so that injection molding, compression molding, or extrusion molding can be considered as possible methods of forming bacterial cellulose composites.
- Do further research on the crystallinity of bacterial cellulose. Diffraction patterns that came off of bacterial cellulose suggested that micron sized piece that was being observed was actually one large crystal.

References:

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