Optimization of Alpha Cellulose and N-Cellulose Solubility in Sodium Hydroxide

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Purpose: Cellulose, the most abundant natural polymer on earth, has been limited in its application to industrial processes due to its low solubility. It is a difficult compound to dissolve largely due to its intra- and intermolecular hydrogen bonding[1]. While not soluble in water, cellulose is soluble in some ionic liquids that have the ability to break the hydrogen bonds that help cellulose retain its crystalline form[2]. However, ionic liquids are not environmentally friendly and are largely made up of organic compounds with high toxicity and low biodegradability[3]. Sodium hydroxide can be used in place of ionic liquids because it fully dissociates, creating ions, that will interfere with hydrogen bonding[4]. Gamma irradiation has been shown to break the 1-4 glycosidic bonds in glucose, providing more available surface area per gram, increasing solubility[5,6]. The goal of this study is to maximize solubility of cellulose utilizing techniques that have a smaller environmental footprint than ionic liquids. This study examines the effects of two variables on cellulose solubility: sodium hydroxide concentration and irradiation dosage.

Methods: This study adapted the Technical Association of the Paper and Pulp Industry (TAPPI) method T 235 for Alkali solubility of pulp at 25 °C. The TAPPI T 235 was designed for pulp extraction and dissolution of degraded cellulose[7]. This method used a similar concentration scheme but excluded the pulp extraction in favor of comparing cellulose dissolution before and after gamma irradiation. It also used the gamma irradiation instrument at the National Institute of Standards and Technology (NIST) to irradiate alpha cellulose (SIGMA-ALDRICH product code: 1002333241, lot number: SLBQ4200V) and medium cellulose fibers (n-cellulose, SIGMA product code: 101809709, lot number: WXBC3692V) to 0, 100, 250, 500, 750, and 1000 kGy at 17 kGy per hour. Samples of 0.75 g of cellulose (alpha and n individually) were dried for 24 hours at 102 °C ± 0.5 °C in a Gallenkamp Microprocessor Controlled Oven (model 1350FM), then soaked in 30 mL of various concentrations of NaOH that included 0% (deionized water), 1%, 7%, 12%, 21.5%, and 25% by weight for 3 hours under constant stirring with a magnetic stir plate (VWR Standard Multi-position Stir Plate). After stirring, the remaining insoluble cellulose was filtered off with a Buchner Flask and a coarse 30 mL sintered glass filter and washed with distilled water. The insoluble cellulose was dried for 24 hours at 102 °C ± 0.5 °C and weighed to determine the amount of soluble cellulose.

Results: Initial non-irradiated samples show peak alpha cellulose dissolution at 7% NaOH. 12% and 25% NaOH have similar dissolution of alpha cellulose, but at a lower rate than the 7% NaOH. Irradiated samples of both alpha cellulose and n-cellulose as well as non-irradiated samples of n-cellulose are still being examined and results will be included at the meeting.

Conclusions: Conclusions will be determined once experimentation is complete.

Relevance to CIRMS: This work is relevant to the mission of CIRMS because it uses radiation for pre-processing cellulose, which will allow it to be more easily dissolved and used as a more environmentally friendly and biocompatible material for both medical and agricultural purposes. CIRMS is relevant to my professional goals because I want to continue my research in this area as I continue my doctoral studies, and potentially continue in this same field after graduation.

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