Effectiveness of Environmentally Friendly Retting Techniques on Industrial Hemp

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Introduction

With the passage of the federal 2014 Farm Bill, which allows state department of agriculture and land grant universities conduct industrial hemp related research, more than 20 states around the U.S. have passed legislation regarding this. Interests have been growing from various stakeholders in understanding more about the planting and applications of industrial hemp. Industrial hemp is a crop produced mainly for seeds and fibers for textiles, food products, seed, oil, animal feed etc. Farmers are interested in growing hemp as a rotation crop for weed suppression, reduced use of pesticides and herbicides, soil improvement, and soil aeration via hemp's deep root systems (Piotrowski & Carus, 2011). In the textile industry, currently hemp fiber production is largely sequestered to industrial applications for ropes, composites, and paper, for which the requirement on fiber quality (cellulose content) is relatively low. Hemp fibers have unique physical and morphological structures, which grant the fibers with excellent mechanical and many other preferred properties (e.g., softness and moisture management) for apparel use. However, due to the lack of research on fiber extraction processes that separate fibers from binding material in the stem and produce fibers with high cellulose content, hemp fibers have not been utilized in apparel industry as widely as other natural cellulose fibers, such as cotton and flax. In this research, three retting agents were experimented to investigate their effectiveness on hemp fiber extraction, i.e., removing the non-cellulose binders, such as pectin and hemicellulose. Environmentally friendly agents were selected for this research to minimize the environmental impact of the retting process. They were enzyme, ethylenediaminetetraacetic acid (EDTA), and enzyme/EDTA combination. Treated hemp fibers were evaluated by weight, chemical composition, thermal properties, and surface morphology.

Material and Methods

Due to the state's legal constraint on obtaining hemp plant, mechanically decorticated hemp fibers without any other treatment were purchased from Bulk Hemp Warehouse (California, USA) and are referred to as neat hemp hereafter. Viscozyme® L (a cellulolytic enzyme mixture containing arabanase, cellulase, β-glucanase, hemicellulase, and xylanase; purchased from Sigma-Aldrich Chemical Co.) was selected for enzyme retting because of its wide range of activities on the different components in the neat fibers. EDTA (99.5%) was purchased from Thermo Fisher Scientific. For the retting process, neat hemp fibers were submerged into the enzyme, EDTA, or enzyme/EDTA solution for two minutes, removed and drained for 30 seconds, and placed in a plastic bag for incubation at 45°C for different amount of times, i.e., 1, 6, 18, and 24 hours. The concentration of enzyme and EDTA were 0.1volume % and 0.01 mol/liter, respectively. Three replicates were made for each treatment. Analytical equipment, including a Nicolet iS 50 fourier transform infrared spectroscopy (FTIR), a Mettler/Toledo TGA/DSC 1 Start System thermogravimetric analysis (TGA), and a FE SEM Quanta 200F scanning electron microscopy (SEM), were used for fiber characterization. Fiber weight before and after treatment was measured and Student's t-test was conducted to compare the influence of different treatment on fiber weight.

Results and Discussion

The weight of fibers (data not included) after all the treatments decreased. When compared sample weights between the neat fibers, fibers treated with enzyme, EDTA, and enzyme/EDTA (with different incubation times of the same agent combined) using students' t-test, the p values for all the comparisons were smaller than 0.0001 except for EDTA and enzyme/EDTA comparison (p = 0.358). The results indicated that all the samples had significant weight loss after treatments with relatively small weight loss for enzyme treatments and big weight loss for EDTA and enzyme/EDTA treatments. The insignificant weight difference between EDTA and enzyme/EDTA treated samples suggested that EDTA played a major role in the combined agent. As can be concluded by analyzing both TGA results (Figure 1.) and SEM images (Figure 2.), the weight loss attributed to the removal of non-cellulose components (pectin and hemicellulose) in the neat fibers. Figure 1. shows the TGA curves for fibers being incubated for 6 hours. At lower temperature (< 250°C, the degradation temperatures for hemicellulose and pectin), the weight loss ratio of neat fibers was larger than treated fibers, suggesting the total or partial removal of the binders. This is also evidenced in SEM images in Figure 2. Individual short fibers were clearly seen in treated large fibers but not in neat fibers. FTIR spectra (not included) of neat and treated fibers were the same, which indicated retting did not change the chemical structure of cellulose.

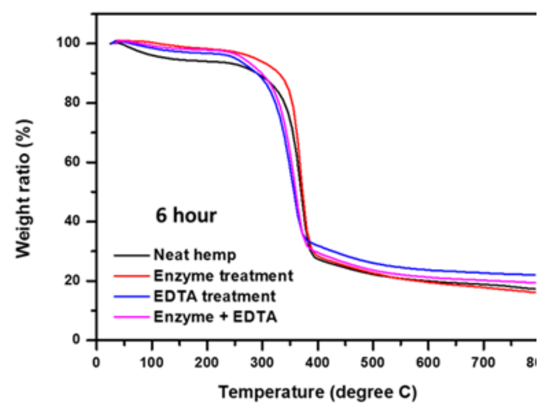

Figure 1. TGA curves of neat hemp fibers and treated fibers for 6 hours.

Conclusion

In summary, all the three agents chosen for this study showed effectiveness in removing non-cellulose contents in hemp fibers. The retting agents and techniques are also environmentally friendly. Further study will be conducted in exploring the effects of different type of enzymes and concentrations, EDTA concentrations, and retting conditions on removing non-cellulose contents and on fiber physical/mechanical properties.

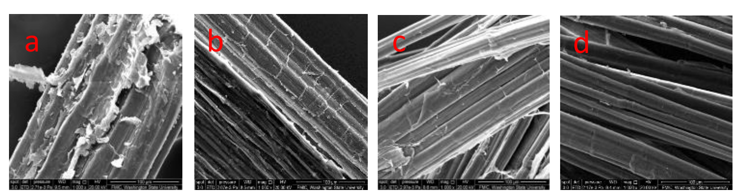

Figure 2. SEM images of (a) neat, and treated hemp fibers with (b) enzyme, (c) EDTA, and (d) Enzyme/EDTA for 6 hours (1000x).

Reference

Piotrowski, S., & Carus, M. (2011). Ecological benefits of hemp and flax cultivation and products. *Nova Institute*, *5*, 1-6.