Pretreatment of hemp fibers for utilization in strong biocomposite materials

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Hemp is the common name for Cannabis sativa cultivated for industrial use. Compared to synthetic fibers (e.g. glass fiber), hemp fibers have many advantages such as low cost, low density (1.5 g/cm3) and high specific strength and stiffness. As a result of increasing environmental awareness, interest in hemp fiber reinforced composites is increasing because of a high potential of manufacturing hemp fiber reinforced polymer composites with acceptable mechanical properties at low cost. In order to expedite the application of natural fibers in polymer composites, hemp fibers need to be treated before being incorporated in matrix polymers to optimize the properties of fibers and fiber reinforced composites. The overall objective of this study was therefore to focus on understanding the correlation between chemical composition and morphology of hemp fibers and mechanical properties of hemp fibers, and furthermore to establish the relationship between the mechanical properties of hemp fiber reinforced composites and the chemical composition and morphology of hemp fibers after different fiber treatments.

The first part of this study investigated the effect of harvest time and stem sections on mechanical properties of hemp fibers in order to correlate the mechanical properties of hemp fibers to their chemical composition and morphology. Harvest time (or growth stage) and stem sections were found to have an effect on the mechanical properties of hemp fibers. The variations in mechanical properties of hemp fibers can be explained by the differences in chemical composition and morphology. Untreated hemp bastfibers with high cellulose content had high stiffness and tensile strength. In addition, the presence of secondary fibers was found to reduce the favorable mechanical properties of hemp fibers. It was our intention to find the key factors that damage fiber properties during traditional field retting. In order to compare and demonstrate the significant effect of the targeted factors, controlled fungal retting was performed using P. radiata Cel 26 and C. subvermispora. Controlled fungal retting with P. radiata Cel 26 and C. subvermispora removed pectin more efficiently than traditional field retting. Fibers with the highest mechanical properties were obtained by controlled fungal retting with P. radiata Cel 26. As a result, composites with P. radiata Cel 26 retted fibers had higher mechanical properties regarding stiffness and tensile strength compared with composites with field retted fibers. The differences in mechanical properties of fibers and fiber reinforced composites were presumably due to the effect of cellulase enzymes activity, which can degrade the cellulose and damage fibers.

Further work was conducted to examine the presence of different enzymes activity during field retting and controlled fungal retting with white rot fungi P. radiata Cel 26. Cellulase, polygalacturonase, galactanase and xyloglucan (XG)-specific endoglucanase activity was determined in the crude extracts from hemp bast fibers after field retting and controlled fungal retting using P. radiata Cel 26 at varied durations (i.e. 7, 14 and 20 days). Cellulase activity was shown to be the crucial factor that caused reduction in mechanical properties of hemp fibers and hemp fiber reinforced composites. The extracts from field retted hemp bast fibers exhibited much higher cellulase enzyme activity compared to extracts from P. radiata Cel 26 retted hemp fibers. The extracts from P. radiata Cel 26 retted hemp fibers had much high polygalacturonase activity compared to that from field retted fibers.

It is certain that cellulase has a negative impact on fiber properties. Mono-component pectinase enzymes were thereby tested on hemp bast fibers combined with hydrothermal pre-treatment. Enhanced removal of pectin from hemp fibers was found to produce a positive impact on hemp fiber reinforced composites. Further work was performed to understand the role of different cell wall components (i.e. pectin, hemicellulose and lignin) in contributing to tensile properties of fiber reinforced composites. Pectin removal was found to increase both composite stiffness and UTS. Hemicellulose removal increased composite stiffness, but decreased composite UTS due to the removal of xyloglucans. The changes in mechanical properties of fiber reinforced composites correlated with chemical composition of differently treated hemp fibers via composite porosity. This may provide a way to reshape and optimize the natural cellulose fibers for composite use. Oxidation of lignin using laccase after treatment with EDTA and EPG increased the mechanical properties of fibers and fiber/epoxy composites. It is suggested that the improvement in mechanical properties was due to polymerization of lignin by laccase resulting in hemp fibers with a stiffer structure. Once part of lignin was removed prior to laccase treatment, a less marked increase in mechanical properties was observed. Modelling of the changes in mechanical properties and physical properties of composites made with differently treated hemp fibers improved understanding of the effect of composite porosity on mechanical properties of unidirectional (UD) hemp fiber/epoxy composites. It was demonstrated that the applied Pretreatment of hemp fibers for utilization in strong biocomposite materials models provide a concept to be used for the evaluation of performance of differently treated fibers in composites. This study has resulted in improved understanding of the role of different components in contributing to the tensile properties of hemp fibers and of fiber treatments to improve the mechanical properties of natural fiber reinforced composites.

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