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INVESTIGATION OF DEFECT FORMATION INDUCED BY BREAKAGE DURING HEMP FIBER EXTRACTION

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ABSTRACT

Hemp (*Cannabis Sativa*) fibers have attracted growing attention as a sustainable alternative to synthetic fibers in various industrial sectors. The diverse applications of hemp fibers demand accurate characterization of their mechanical properties. This study investigates the mechanical impact induced during the breaking stage of hemp fiber extraction. Compression and bending tests were conducted to assess the potential formation of structural defects. To further analyze the microstructure, computed tomography scans were performed on the tested samples. The imaging results revealed the presence of kink bands and fiber detachment following the bending tests. These findings support the hypothesis that the breaking stage may introduce defects into hemp fibers, which can influence their mechanical performance in downstream applications.

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INTRODUCTION

Mechanical extraction steps are generally used to extract hemp fibers. During breaking of the stems, fiber defects such as kink bands may appear in their structure, leading to degradation and high variation in mechanical properties of these fibers [1]. Prior studies include characterization of these defects and their effect on fiber properties. Quereilhac et al. studied these damage mechanisms at the submicron level using X-ray tomography [2].

Singhal et al. [3] conducted a study to reduce defects during the extraction of natural fibers. Compression was performed on the stem to identify the breaking properties of the xylem. A study on bending was also performed to identify the conditions of breaking of the samples. A gear geometry with two teeth was proposed to reproduce the 4-point bending test conditions. Finally, SEM scans were performed to identify possible defects in the fibers added by previous treatments. The SEM demonstrated the existence of kink bands at the surface of the fibers and splitting, but they did not give information regarding the mechanisms leading to their appearance.

Braud et al. [4] demonstrated different ways of breaking the stems after bending, identifying a break in four pieces and marks generated by the contact of the indenter, decohesion, longitudinal splitting and transversal splitting were also identified.

To assess structural damage during the extraction process, the specimens were initially subjected to longitudinal compression until complete rupture of the stem occurred, resulting in its division into multiple fragments. These fragments were subsequently evaluated under flexural loading (3-point bending).

RESULTS AND CONCLUSIONS

Analysis of the compression test results revealed a failure mode that was consistent with previously reported patterns in the literature, with specimens typically fracturing into 4 to 8 fragments of approximately equal dimensions.

X-ray tomography performed after the compression test revealed no detectable defects, with the internal structure of the sample appearing unchanged compared to its pre-test condition. In contrast, the post-flexure tomography exhibited notable structural alterations, including the formation of multiple kink bands distributed across the sample width, as well as evidence of fiber–stem and fiber-fiber interfacial delamination and broken xylem (Fig. 1).

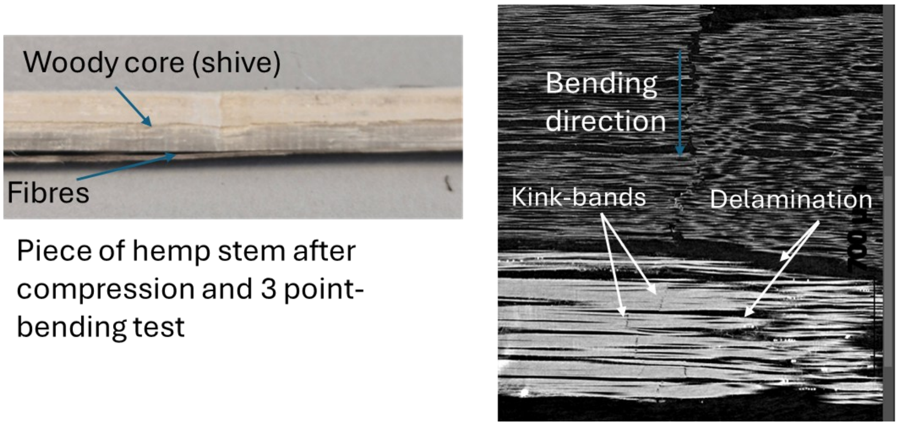

Fig. 1 Quarter piece of hemp stem and tomography image after bending test of the same piece

The results demonstrated that stem fracture induced by compression does not lead to the formation of structural defects within the fibers. The kink-bands are generated during the bending of stem pieces at the same time as fiber separation throughout the entire cross-section of the sample. Different bending scenari were tested and the distribution of kink-bands investigated Hypothesis regarding the mechanisms at the origin of kink-band appearance during the bending of stem pieces will be discussed in regards of the different bending scenari.

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