Study on Macrostructure and Fourier Transform Infrared Spectroscopy of Cornstalk

Yan XUa,1, Yinlong JIANGb, Huxia YANGa and Yungao CAIa

a College of Engineering and Technology, Baoshan University, Baoshan 678000, Yunnan, China
b College of Engineering, South China Agricultural University, Guangzhou 510642, Guangdong, China

Abstract. As a biological by-product, cornstalk will pose a huge threat to the development of sustainable agriculture and environmental protection if it is not fully utilized. In this study, the macrostructure was characterized by optical camera and the chemical composition of cornstalk rind and cornstalk pith was characterized by Fourier transform infrared spectroscopy (FTIR). The test results show that the cornstalk was divided into rind and pith macroscopically, the cornstalk is smooth outside, and the pith is a sponge-like structure, the fiber structure evenly distributed on the pith. FTIR analysis showed that the cornstalk was presumed to be aliphatic compounds containing C-H chains and rich in fatty acids and/or ketones, and the main components include cellulose and lignin. The results of this study provide new inspiration and reference for the post-processing of cornstalks.

Keywords. Cornstalk, macrostructure, chemical composition

1. Introduction

As an important biomass resource and renewable green energy, cornstalk has the characteristics of large output, high calorific value and high nutritional value. For a long time, cornstalks are usually burned as fuel or processed into silage, fertilizer, etc. [1-3]. However, cornstalks contain a large amount of natural fibers. In recent years, the extraction of natural fibers from corn stalks and their applications in the construction industry, composite material industry and other fields have been carried out. Boufi et al. produced cellulose nanofibers from cornstalk by a conventional high-speed blender [4], Chen et al. carried out a study on the performance investigation of cornstalk fibrous materials in asphalt concrete [5], and Vo et al. explored the correlation between genotype biochemical characteristics and mechanical properties of cornstalk-polyethylene composites [6]. However, these studies have carried out research on the properties of cornstalks fiber from a macroscopic perspective, and the research on the microscopic scale is relatively weak.

Exploration of plant stalks fiber has important reference value for in-depth research in the fields of crop lodging resistance, increasing yield and income, mechanized...
harvesting, deep processing and reuse of by-products, and preparation of biomimetic materials [7-9]. He et al. analyzed the tensile properties and fiber morphology of cornstalk rind [10], and Reddy et al. developed a new method to extract the fibers from cornstalk by studying the structure and properties of cornstalk fibers [11]. Huang et al. analyzed the stiffness changes of maize fiber bundles through multi-scale simulation, which provided a certain reference for breeding research of maize lodging resistance [12,13].

With the improvement of modern instrument technology, such as spectrum technology, it is of great application prospect to explore the properties of natural plant fiber by using spectrum, and integrate with its macroscopic distribution, so as to explore its physical and chemical properties, mechanical properties, and to dig out biomass resources and green energy such as crop stalks have great application prospects [14]. In the study of cornstalks, He et al. performed FTIR analysis to reveal the influence of internal factors on the surface wettability of cornstalk rinds [15]. Zhao et al. carried out the surface characterization of cornstalk superfine powder study by FTIR and XRD [16]. Zou et al. used FTIR to characterize the composition of the three parts of corn cob pith, wood ring and glume. Reveal the contribution of fiber components in the mechanical properties, which provide a reference for the deep processing and industrial application of corn cob [17].

In this study, cornstalk was taken as the research object, and its macroscopic structure was studied and its chemical composition was characterized, and the difference between cornstalks rind and pith was discussed. The remainder of this study is summarized below. The second section introduces the experimental materials and methods, including the preparation of cornstalk samples, and the characterization techniques and methods of chemical composition. The third section introduces the test results and analyzes the difference between the macroscopic distribution and chemical composition of cornstalk rind and pith fibers by FTIR. The fourth section summarizes the research progress and results of the full article.

2. Materials and Methods

2.1. Experimental Materials

The experimental materials were selected from the normally developed Zhuoyu 299 corn planted in Longyang District. After the corn was harvested, the middle part between the third and fourth nodes above the ground was selected as the research samples. The obtained experimental samples were first ultrasonically cleaned with deionized water for 120s to remove various impurities physically adsorbed on the surface. Then, it was vacuum dried in a vacuum drying oven at 40°C for 48 h. The test samples after ultrasonic cleaning and vacuum drying were used for follow-up studies.

2.2. Macrostructural Observations

Selected experimental samples of cornstalks were photographed with optical cameras for their surface, axial-section and cross-section photos for statistics and analysis of their macrostructural parameters.
2.3. Chemical Composition Test

After ultrasonic cleaning and vacuum drying, cornstalk rind and cornstalk pith were selected respectively, without any pretreatment. The chemical composition was characterized using a Fourier transform infrared spectroscopy (FTIR, Bruker alpha, Germany) attenuated total reflection accessory (ATR-FTIR) in the wave number range of 4000 cm\(^{-1}\) to 500 cm\(^{-1}\).

3. Results and Discussion

3.1. Macroscopic Structure

Cornstalk was the backbone of the corn plant. As shown in Figure 1a, a section of cornstalk between two adjacent nodes was selected. The middle position was selected, and the macroscopic cross-section was shown in Figure 1d. The interfaces of rind and pith both are approximately annular, and the areas of the whole, pith, and rind can be calculated by the following equations:

\[
S_w = \pi R_1^2 \\
S_p = \pi R_0^2 \\
S_r = \pi R_1^2 - \pi R_0^2
\]

where, \(S_w\), \(S_p\) and \(S_r\) mean the area of the whole, the pith, and the rind, respectively, \(R_0\) and \(R_1\) mean the radius of the section of the pith and rind, respectively.

![Figure 1. Macrostructure of cornstalks.](image)
From Figure 1, we can see that the cornstalk is smooth in outside, and the pith is a sponge-like structure. The axial-sectional structure is shown in Figure 1c. On the cross-sectional structure, we can clearly see the boundary between the pith and the rind, and the fiber structure evenly distributed on the pith can be seen with eyes. We believe that such a distinct inner and outer bilayer structure is of great significance for the further processing of cornstalks and the preparation of biomimetic materials.

For the four selected experimental samples, the cornstalk pith sample was obtained by peeling off all the rind with a utility knife, A vernier caliper was used to measure the macroscopic geometric dimensions, and the cross-sectional dimensions of the samples were obtained as shown in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole diameter (mm)</td>
<td>24.56</td>
<td>23.40</td>
<td>22.62</td>
<td>24.00</td>
</tr>
<tr>
<td>Pith diameter (mm)</td>
<td>19.66</td>
<td>22.86</td>
<td>19.44</td>
<td>19.83</td>
</tr>
</tbody>
</table>

3.2. Chemical Composition Analysis

Figure 2 shows the FTIR obtained by scanning the cornstalk rind and cornstalk pith. It is found that the wave number of the absorption peaks of the rind and pith infrared spectra is almost the same, and the main difference was the absorption peak intensity. Summary analysis of 17 distinct characteristic peaks is shown in Table 2 [14,17].

The comparative analysis of the absorption peaks of the cornstalk pith and cornstalk rind, it is found that the difference in the intensity of the absorption peaks is mainly expressed in three aspects. First, at 3327cm⁻¹ and 1249cm⁻¹, -OH descending stretch and -OH bending vibration, respectively, where the absorption peak intensity of the cornstalk pith was still weaker than that of cornstalk rind. Secondly, at 2928cm⁻¹ and 2849cm⁻¹, it is mainly caused by the stretching vibration of C-H in methyl and/or methylene, At the same time, the C-H scissoring vibration band in the methylene group can be observed at 1455cm⁻¹, at the wave number of 1366cm⁻¹ and 897cm⁻¹, C-H bending vibration band can be observed, and a C-H rocking vibration band can be observed at 785cm⁻¹. Among the above absorption peaks, the stretching vibration of C-H was almost the same on the cornstalk pith and cornstalk rind, the absorption peak intensity of scissoring and bending
vibration on the cornstalk pith was significantly weaker than that of the cornstalk rind, and the absorption peak intensity of the rocking vibration on the cornstalk pith was significantly stronger than that of cornstalk rind. It speculates that cornstalk was an aliphatic compound containing with C-H chain. In addition, at 1730cm\(^{-1}\) and 1651cm\(^{-1}\), it was mainly C=O stretching vibration, at 1605cm\(^{-1}\), it was Aromatic skeletal vibration plus C=O stretching, and at the wave number of 1515cm\(^{-1}\), it was Aromatic skeletal vibration. At the position containing C=O functional group, the absorption peak intensity of cornstalk pith was obviously weaker than that of cornstalk rind, and it is opposite at 1515cm\(^{-1}\). at the wave number of 1166cm\(^{-1}\) and 1048cm\(^{-1}\), it is mainly C-O stretching vibration, and C-C and C-O vibration at 1312cm\(^{-1}\), C-C stretching vibration at 1421cm\(^{-1}\), C-C=O vibration at 665cm\(^{-1}\), at the above wave numbers, the absorption peak intensity on cornstalk pith was also significantly weaker than that on cornstalk rind, we speculate that cornstalk was rich in fatty acids and/or ketones.

<table>
<thead>
<tr>
<th>No.</th>
<th>Wave number/cm(^{-1})</th>
<th>Functional groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3327</td>
<td>-OH descending stretch</td>
</tr>
<tr>
<td>2</td>
<td>2928</td>
<td>C-H stretching vibration</td>
</tr>
<tr>
<td>3</td>
<td>2849</td>
<td>C-H stretching vibration</td>
</tr>
<tr>
<td>4</td>
<td>1730</td>
<td>C=O stretching vibration</td>
</tr>
<tr>
<td>5</td>
<td>1651</td>
<td>C=O stretching vibration</td>
</tr>
<tr>
<td>6</td>
<td>1605</td>
<td>Aromatic skeletal vibration plus C=O stretching</td>
</tr>
<tr>
<td>7</td>
<td>1515</td>
<td>Aromatic skeletal vibration</td>
</tr>
<tr>
<td>8</td>
<td>1455</td>
<td>C-H scissoring vibration</td>
</tr>
<tr>
<td>9</td>
<td>1421</td>
<td>C-C stretching vibration</td>
</tr>
<tr>
<td>10</td>
<td>1366</td>
<td>C-H bending vibration</td>
</tr>
<tr>
<td>11</td>
<td>1312</td>
<td>C-C and C-O vibration</td>
</tr>
<tr>
<td>12</td>
<td>1249</td>
<td>-OH bending vibration</td>
</tr>
<tr>
<td>13</td>
<td>1166</td>
<td>C-O stretching vibration</td>
</tr>
<tr>
<td>14</td>
<td>1048</td>
<td>C-O stretching vibration</td>
</tr>
<tr>
<td>15</td>
<td>897</td>
<td>C-H bending vibration</td>
</tr>
<tr>
<td>16</td>
<td>785</td>
<td>C-H rocking vibration</td>
</tr>
<tr>
<td>17</td>
<td>665</td>
<td>C-C=O vibration</td>
</tr>
</tbody>
</table>

4. Conclusions

In this study, the macrostructure and composition of cornstalks were characterized by optical camera and Fourier transform infrared spectroscopy (FTIR), respectively. The findings of this study can be summarized as follows:

(1) The section of cornstalk was approximately circular, mainly composed of cornstalk rind and cornstalk pith, the cornstalk is smooth in outside, and the pith is a sponge-like structure, the fiber structure evenly distributed on the pith.

(2) Cornstalk was mainly composed of cellulose, lignin and other components, and the difference in chemical composition between the components indirectly leads to the difference in mechanical properties. Fourier transform infrared spectroscopy (FTIR) analysis showed that the cornstalk was presumed to be aliphatic compounds containing C-H chains and rich in fatty acids and/or ketones. From the perspective of chemical
composition, the difference was mainly reflected in the difference in the intensity of each absorption peak.

As a biological by-product, the full utilization of cornstalk has great potential for the development of sustainable agriculture and environmental protection. Cornstalk has a gradient-distributed macrostructure, and different microstructures of cornstalk rind and cornstalk pith. The analysis of the macroscopic structure, chemical composition and functional groups of cornstalks can provide reference in the field of deep-processing and reuse of cornstalks, and promote the sustainable development of agriculture and environmental protection.

References