Available online at www.sciencedirect.com
SCIENCE DIRECT®

Industrial Crops and Products 23 (2006) 1–8

INDUSTRIAL CROPS AND PRODUCTS
AN INTERNATIONAL JOURNAL

www.elsevier.com/locate/indcrop

Bioprocess preparation of wheat straw fibers and their characterization

Mohini Sain *, Suhara Panthapulakkal

Center for Biocomposites and Biomaterials Processing, Faculty of Forestry, 33 Willcocks Street, University of Toronto, Toronto, Canada M5S 3B3

Received 23 August 2004; accepted 12 January 2005

Abstract

Plant fiber reinforced thermoplastic composites have gained much attraction in structural applications such as building and automotive products. Agricultural residues such as wheat straw, bagasse, and corn stover can also be exploited as readily available natural fiber resources for similar applications. The objective of this study was to extract fibers from wheat straw and also to determine the usefulness of fungal retting of wheat straw before extracting the fibers. Wheat straw was mechanically defibrillated using a laboratory-scale mechanical refiner before and after fungal retting. Fiber characteristics such as physico-chemical and mechanical properties, surface characteristics, and thermal properties of the resultant fibers were measured in order to explore the possibilities of using the fibers as reinforcing materials. Retted fibers were stronger than un-retted fibers. The length and diameter of the retted fibers were lower than the un-retted fibers. FT-IR spectroscopic analysis of the wheat straw fibers indicated the fractional removal of hemicelluloses and lignin from the retted fiber. X-ray photoelectron spectroscopy (XPS) of the fibers showed the partial removal of extractives from the surface of the retted fibers. Also, the oxygen to carbon ratio (O/C) of the fibers illustrated that there is more lignin type surface structure for both retted and un-retted fibers. However, slightly higher ratio of oxygen to carbon in the retted fiber indicated a more carbohydrate-rich fiber than the un-retted fiber. Thermal degradation characteristics demonstrated the suitability of processing wheat straw fibers with thermoplastics.

Keywords: Bio-processing; Wheat straw; Retting; Fiber characteristics; Cellulosic fibers

1. Introduction

In the past two decades, use of plant fibers such as flax, hemp, sisal, and jute for manufacturing structural as well as semi-structural fiber reinforced thermoplastics have been the subject of extensive research (Gassan and Bledzki, 1997; Mwaikambo and Ansell, 2002; Jayaraman, 2003; Prasad and Sain, 2003; Panthapulakkal et al., 2004; Pervaiz and Sain, 2004). The research interests in these lignocellulosic materials are attributed to the advantages offered by these fibers over traditional reinforcing materials such as low density, high

* Corresponding author. Tel.: +1 416 946 3191; fax: +1 416 978 3834.
E-mail address: m.sain@utoronto.ca (M. Sain).

0926-6690/$ – see front matter © 2005 Published by Elsevier B.V.
doi:10.1016/j.indcrop.2005.01.006

specific properties, non-abrasive nature, high level of filler loadings, availability, renewability, safe working environment, etc. (Woodhams et al., 1984; Pervaiz and Sain, 2004; Rouison et al., 2004). Agricultural crop residues such as cereal straw, corn stalk, cotton, bagasse, and grass are produced in billions of tonnes around the world represent an abundant, inexpensive, and readily available sources of lignocellulosic biomass. Among these enormous amounts of agricultural residues, only a minor quantity of residues is reserved as animal feed or household fuel and a major portion of the straw is burned in the field creating environmental pollution. The exploration of these inexpensive agricultural residues as bioresource for making industrial products will open a new avenue for the utilization of agricultural residues by reducing the need for disposal and environmental deterioration through pollution, fire, and pests and at the same time add value to the creation of rural agricultural based economy.

Wheat straw is one of the most important agricultural residues. It is an annually renewable fiber resource that is available in abundant quantity in many regions of the world. In Canada, tonnes of unused wheat straw residues are generated every year and only a very small percentage has been used for applications such as feedstock and energy production. Straw is similar to wood and could also be considered as a natural composite material. It consists mainly of cellulose, hemicellulose, and lignin (White and Ansell, 1993; Xiao et al., 2001). During the past 20 years, the use of straw as a potential fiber for making paper and particleboard composites has gained much attention (White and Ansell, 1993; Young, 1996; Hornsby et al., 1997; Han et al., 1998; Wang and Sun, 2002). Extraction of fibers from the plant stems is achieved by various methods such as mechanical, physical, and steam explosion techniques (Young, 1996). Retting is a process of controlled degradation of the plant stem to allow the fiber to be separated from the woody core, and thereby, improving the ease of extraction of the fibers from the plant stems. Microbial/enzymatic retting is one of the widely used techniques to extract good quality cellulosic fibers from the agricultural plants such as hemp, flax, and jute (Sharma, 1987; Henriksson et al., 1997; Akin et al., 2000; Himmelsbach et al., 2002). The enzymes produced by the fungus or bacteria weaken and/or remove the pectinic glue that bonds the fiber bundles together and release the cellulosic fibers from the fiber bundle.

In this research work, we explored the use of a fungus, which was isolated from the bark of an elm tree, for retting of wheat straw to generate wheat straw fibers that can be used as reinforcing materials for thermoplastics. Fungal retting followed by mechanical defibrillation was carried out to generate fibers. Characterization of fibers has to be done before processing them into composites to establish their potential as reinforcements. The processed fibers were characterized for their physical, mechanical, spectroscopic, and thermal properties, and compared with the un-retted wheat straw fibers.

2. Experimental procedures

2.1. Materials used

Wheat straws obtained from the local farmers were cut 4–5 cm long and were used for fiber generation. The microbe used was named S1, a fungus isolated from the bark of an elm tree by M. Hubbes and R. Jeng, University of Toronto. The fungus, belonging to the group of fungus Imperfecti, was taxonomically identified as *Apospheria* sp.

2.2. Preparation of culture

Cultivation of the fungus was performed at room temperature in liquid culture medium supplemented with potato dextrose broth (PDB). After the heat sterilization of the media, small blocks of fungus were transferred into the media and were placed on a rotary shaker at room temperature until a heavy suspension of spores of the fungus (3–4 weeks) was obtained.

2.3. Fiber preparation

About 200 g of the cut straw was soaked in water overnight and was mechanically defibrillated using a laboratory-scale Sprout–Waldron refiner where the wet straw was sheared between two grooved discs, one rotating against the other stationary disc. The refining was done by passing the straw three times through the refiner with a gap width of 2–3 mm. The