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International Biodeterioration & Biodegradation 58 (2006) 162–167

INTERNATIONAL BIODETERIORATION & BIODEGRADATION

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Study of the structure of biodegraded wood using the water vapour sorption method

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Received 11 July 2005; accepted 6 June 2006
Available online 10 August 2006

Abstract

The dynamics of the biodegradation of wood by brown-rot fungi (*Coniophora puteana*, *Poria placenta*, and *Gloephyllum trabeum*) was investigated by the water vapour sorption method. The change in wood microstructure characteristics (specific surface and concentration of surface hydrophilic centres) with increasing exposure time correlated with reduction in mass and change in composition. Two-to-eight-nanometer-wide micropores, whose size and volume depended on the fungal species and exposure time, appeared in the wood. Methodological aspects of the application of sorption methods should be taken into account in the interpretation of the results.

Keywords: Wood; Brown-rot fungi; Biodegradation; Water vapour sorption method

1. Introduction

It is known that brown-rot fungi actively degrade wood, utilizing mainly the carbohydrate part of the cell wall. Not only the cell composition, but also its structure, is changed considerably.

One of the important questions that are discussed in the literature (Flournoy et al., 1991; Hill et al., 2005) is how enzymes (or their precursors) penetrate into the rather dense cell wall. The dense wall of dry wood contains almost no micropores. For example, birch wood wall pore volume, determined from nitrogen sorption, is only $0.002\,cm^3\,g^{-1}$ (our data). Such wood is not subject to rotting (Eaton and Hale, 1993).

When in water vapour, wood swells, and its microstructure changes. The pore volume and inner surface increase dramatically. We proved this mechanism of swelling experimentally for cellulose (Chirkova et al., 2004), but it is true for any expandable sorbents, especially for wood. To assess the microporosity of swollen wood, Flournoy et al. (1991) and Hill et al. (2005) have used the method of sorption of a range of molecules of definite sizes from dilute aqueous solutions (Stone and Scallan, 1968).

In our opinion, however, this method is not correct. The point is that the dissolved substances decrease the water activity, and this decrease depends on the nature and size of the molecules of the solute. As a result, the swelling of wood tends to decline, and the microstructure of the cell wall differs, in the absence of these substances.

We used the water vapour sorption method for the investigation of wood microstructure after attack by brown-rot fungi (Irbe et al., 2001, 2006). Cell wall micropores, whose volume and size depended not only on the fungal species, but also on the exposure time, were found.

Despite the fact that many studies have been done, many aspects of the biodegradation of wood remain unclear; this is mainly due to the complexity of the systems. In particular, there is the problem of how enzymes penetrate the wood cell wall. Apart from this, when applying physico-chemical methods, methodological problems arise; because degrading samples are being investigated, they contain unutilized fragments of carbohydrates.

In the present work, an investigation of the dynamics of the change in the microstructure of pine wood under the action of brown-rot fungi was undertaken by the water vapour sorption method. Some methodological aspects of

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doi:10.1016/j.ibiod.2006.06.005

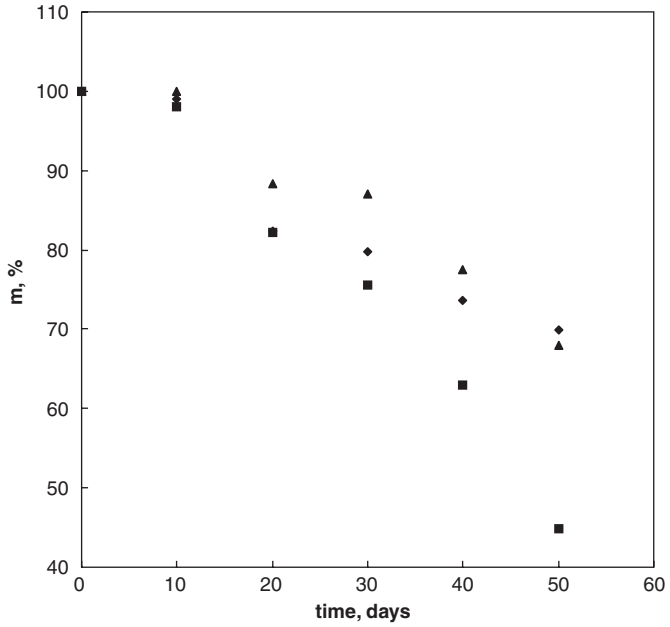

Fig. 1. Change in mass of pinewood in the course of decay by: *C. puteana* (■); *P. placenta* (▲); *G. trabeum* (◆).

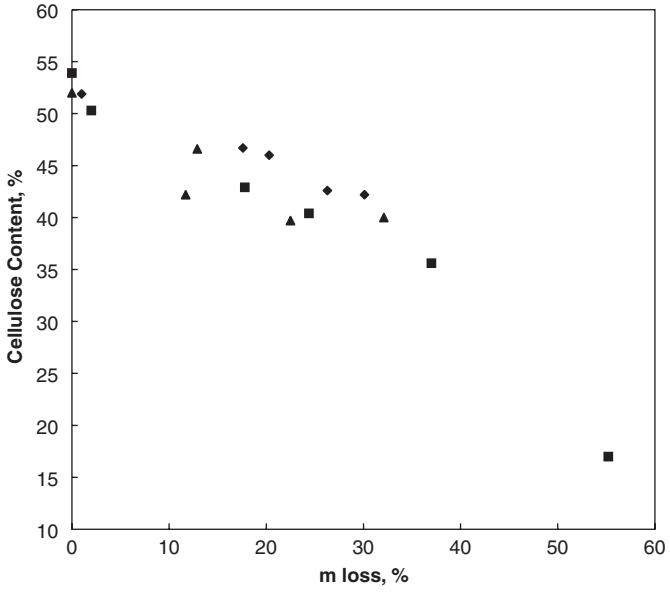

Fig. 2. Cellulose content in wood samples versus the mass loss after fungal attack: (■)—*C. puteana*; (▲) —*P. placenta*; (◆)—*G. trabeum*.

the application of physico-chemical methods to study wood biodegradation processes were also considered.

2. Materials and methods

Three fungal strains were used: *Coniophora puteana* (Schum.:Fr.) Karst. (BAM Ebw.15), *Poria placenta* (Fr.) Lars. et Lomb. (FPRL 280), and *Gloeophyllum trabeum* (Pers.: Fr.) Murr. (BAM Ebw. 109). Isolates were maintained on malt agar slants at 6 °C. Mycelium was transferred aseptically to petri dishes containing 5% malt extract and 3% bacto agar (Ferak, Berlin), pH 6.4, and incubated at 22 °C and 70% RH. Mycelial plugs were transferred to Kolle flasks for the wood decay test.

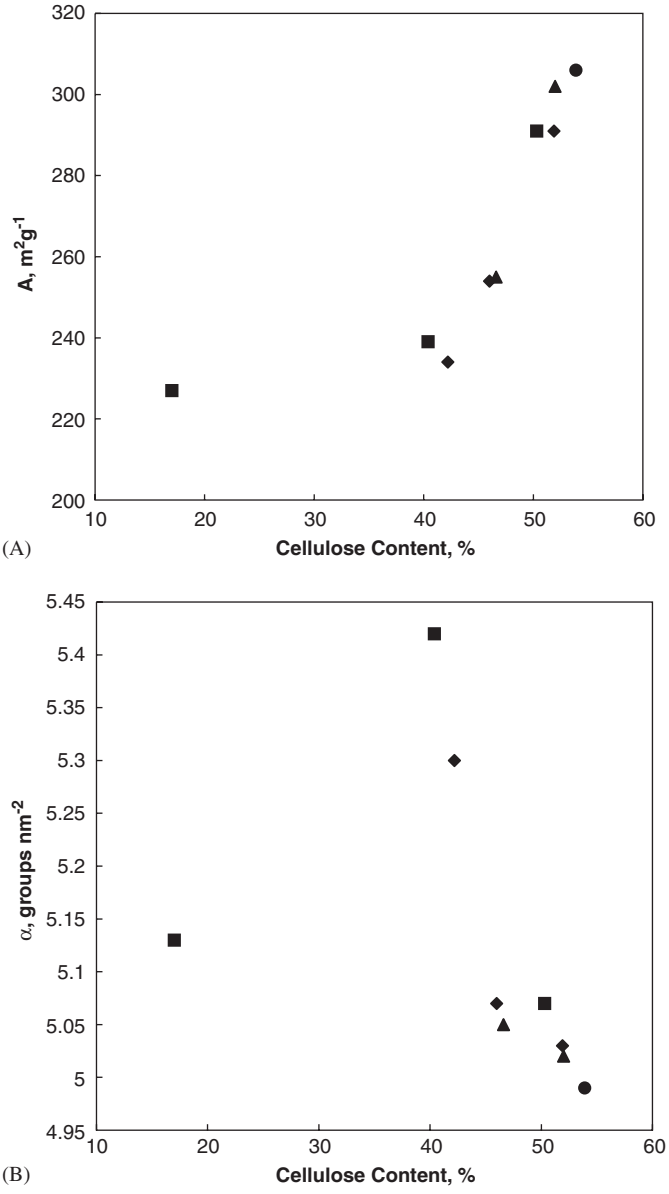

Fig. 3. Dependence of structural characteristics of biodegraded wood on cellulose content: (◆)—*C. puteana*; (■)—*P. placenta*; (▲)—*G. trabeum*.

Scotch pine (*Pinus sylvestris*) sapwood blocks (20 × 20 × 5 mm, "small" samples, for the 3–50 day tests and 50 × 25 × 15 mm, "large" samples, for the 1–4 month tests) were exposed to the fungi at 22 °C and 70% RH. Test procedures were carried out according to European standard EN 113 (1996), in compliance with which the blocks before and after exposure were oven dried at 103 ± 2 °C. One of the series (exposure time 3–50 days) was investigated without preliminary oven drying after exposure. The mass loss was calculated from dry mass before and after the test.

The cellulose content ($MM \geqslant 10\,000$) in the wood samples was determined by the Kuerschner method and the lignin content by the Klason method.

The measurement of water vapour sorption–desorption isotherms has been described (Irbe et al., 2006). Wood samples after fungal degradation were milled, and a fraction 0.5–1.0 mm was taken for measurement of the isotherms.

The isotherms were analysed by the comparative method, in combination with the Brunauer, Emmet, Teller (BET) method (Chirkova et al., 2004). The following characteristics of the sample microstructure were determined: accessible specific surface (**A**, $m^2 g^{-1}$), mass and surface