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Evaluation of the antifungal effects of bio-oil prepared with lignocellulosic biomass using fast pyrolysis technology

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HIGHLIGHTS

- ▶ Biooil was produced by fast pyrolysis technology with lignocellulosic biomass.
- ▶ Antifungal effect of biooil was evaluated using *T. palustris* and *T. versicolor*.
- ▶ Chemical components agglomerated in the inner part of wood and formed clusters.
- ▶ The clusters acted as wood preservatives and were identified as phenolic compounds.

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ABSTRACT

This study was performed to investigate the utility of bio-oil, produced via a fast pyrolysis process, as an antifungal agent against wood-rot fungi. Bio-oil solutions (25–100 wt.%) were prepared by diluting the bio-oil with EtOH. Wood block samples (yellow poplar and pitch pine) were treated with diluted bio-oil solutions and then subjected to a leaching process under hot water (70 °C) for 72 h. After the wood block samples were thoroughly dried, they were subjected to a soil block test using *Tyromyces palustris* and *Trametes versicolor*. The antifungal effect of the 75% and 100% bio-oil solutions was the highest for both wood blocks. Scanning electron microscopy analysis indicated that some chemical components in the bio-oil solution could agglomerate together to form clusters in the inner part of the wood during the drying process, which could act as a wood preservative against fungal growth. According to GC/MS analysis, the components of the agglomerate were mainly phenolic compounds derived from lignin polymers.

1. Introduction

Bio-oil produced from the fast pyrolysis of lignocellulosic biomass is attractive because it has the potential to be used as a fuel or to be upgraded into higher value products (Onay, 2007). Fast pyrolysis thermolytically transforms organic materials into volatiles that can be condensed into liquid form. Bio-oil composed of a very complex mixture of oxygenated hydrocarbons can substitute for heavy oil or coal in many static applications for the generation of electricity (Bridgwater and Peacocke, 2000). Although fast pyrolysis is considered one of the more promising candidates for liquid fuel production (Oasmaa et al., 2003), bio-oil has been tested in many other industrial fields. A range of chemicals including food flavorings, levoglucosan, hydroxyacetaldehyde, fertilizers, and agri-chemicals can be extracted or derived from bio-oil. In addition, bio-oil has been tested as an alternative wood preservative (Meier et al., 2001; Mourant et al., 2007). Because bio-oil contains a considerable amount of phenolic compounds derived from lignin, it exhibits wood-preserving properties.

The wood preservation industry is undergoing rapid and dramatic changes. The use of chromated copper arsenate (CCA) has been restricted to industrial applications due to public health concerns and disposal issues. Therefore, the wood preservation industry has been looking for environmentally friendly, alternative wood preservatives. Several alternatives have been developed in an effort to replace CCA with sustainable wood preservatives. Since copper is widely known for its fungicidal properties (Mourant et al., 2009), novel biocides containing a copper element such as copper azole (CuAz) and ammoniacal copper quaternary have become commonplace in the wood preservation industry (Ahn et al., 2010). However, because of high aquatic toxicity and the high cost of these preservatives, environmental and economic concerns related to these biocides remain (Mohan et al., 2008). Therefore,

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Table 1
Physical properties of bio-oil produced with YP.

Properties	Value
Water content (wt.%)	25.4
pH	2.3
Viscosity (cSt)	20.0
Elemental analysis (wt.%)	
Carbon	40.2
Hydrogen	6.8
Oxygen[a]	52.8
Nitrogen	0.3
Higher heating value (MJ kg^{-1})	16.1

[a] By difference.

several economically and environmentally viable preservatives have been newly developed. For instance, natural resources such as soy protein products (Yang et al., 2006), okara waste (Ahn et al., 2008), and lignin (Gargulak and Lebo, 2000) have all been utilized as raw materials in the search for a new preservative system.

The aim of this study was to assess the applicability of bio-oil based material as a natural source of preservatives by determining the efficacy of the preservatives against two representative wood-rot fungi: *Tyromyces palustris* and *Trametes versicolor*. The treatability and leachability of bio-oil produced from fast pyrolysis of yellow poplar (YP) were also investigated with varying concentrations of bio-oil solutions to determine the stability of wood blocks treated with the preservatives.

2. Materials and methods

2.1. Bio-oil production

YP (*Liriodendron tulipifera*) sawdust was used to produce bio-oil in a lab-scale fluidized-bed fast pyrolyzer. The sawdust was air dried to approximately 8% moisture content. The raw sample was ground and screened to a particle size of 0.5–0.7 mm. Fast pyrolysis of the sample was performed at 500 °C with a 1.9 s pyrolysis product residence time. The bio-oil produced from YP was characterized by several analytical methods. A Karl-Fischer titration with hydranal composite five solutions was used to determine the water content of the bio-oil. The elemental composition (carbon, hydrogen, nitrogen, and oxygen) of the bio-oil was analyzed by a LECO CHNS-932 elemental analyzer. The oxygen content was determined by difference. The kinetic viscosity (at 40 °C), pH value, and calorific value of the bio-oil were also determined by a capillary viscometer, pH meter, and bomb calorimeter (Parr 6400), respectively.

2.2. Preparation of wood blocks and bio-oil treatment

Sapwood portions of defect-free pitch pine (*Pinus rigida:* PP) and YP (*L. tulipifera*) wood blocks were prepared with dimensions of 2.54 × 2.54 × 2.54 cm. Bio-oil solutions (25–100 wt.%) were prepared by diluting the bio-oil with ethyl alcohol. The wood blocks were immersed in each bio-oil solution for 20 min under a vacuum (66.7 kPa), followed by exposure to 20 min of pressure (1176 kPa) in a laboratory pressure cylinder (Ahn et al., 2008, 2010). After the bio-oil treatment, the wood blocks were allowed to air dry until the solvent evaporated. The weight gain of each block after submersion in the bio-oil solution was measured to investigate the treatability of the bio-oil solution. The bio-oil-treated wood blocks were subsequently subjected to a leaching test in 70 °C distilled water for 72 h, after which they were dried out and weighed. The weight loss of the wood blocks during the leaching test was defined as the leachability of each bio-oil solution. Finally, after the bio-oil treatment and leaching test, eight wood blocks (four YP and four PP) were prepared for the soil block tests.

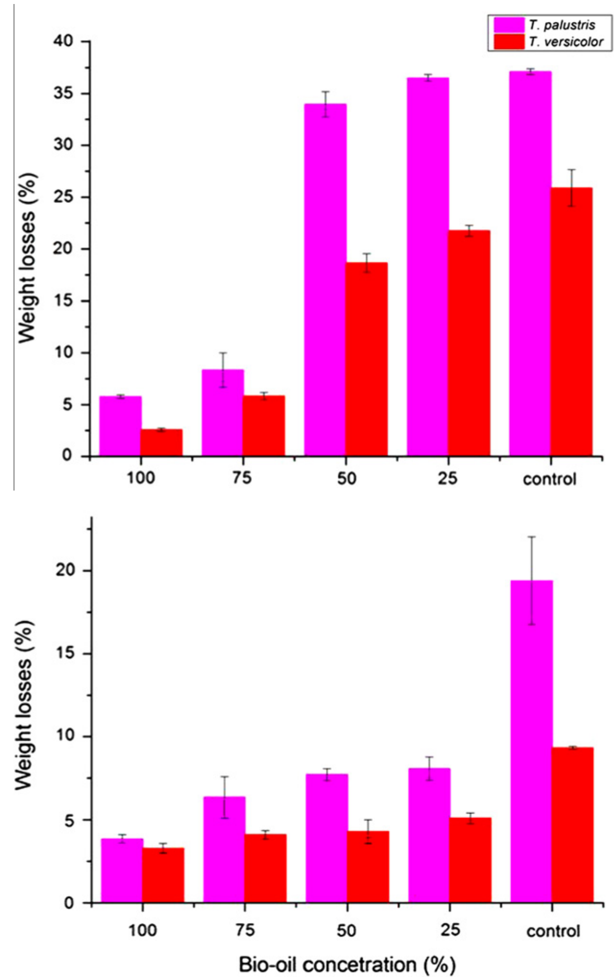

Fig. 1. The weight loss of leached wood blocks of YP (top) and PP (bottom) after soil block test with *T. palustris* and *T. versicolor*.

2.3. Soil block tests

Soil block tests were performed to evaluate the efficacy of the bio-oils as a wood preservative against the growth of wood-rot

Table 2
Treated, leached and net uptake of bio-oil in YP and PP wood blocks at different bio-oil concentrations.

Bio-oil concentration (%)	YP			PP		
	Treated (kg m^{-3})	Leached (kg m^{-3})	Net uptake (kg m^{-3})	Treated (kg m^{-3})	Leached (kg m^{-3})	Net uptake (kg m^{-3})
100	340	126	214	198	81	117
75	251	102	149	71	44	27
50	75	42	33	33	24	9
25	88	52	36	43	26	16