INFLUENCE OF MOISTURE ON BROWN-ROT FUNGAL ATTACK ON WOOD

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ABSTRACT

Southern pine solid wood and wood fiber were reacted with acetic anhydride to various acetyl weight gains. The equilibrium moisture content (EMC) was determined on these specimens at 30%, 65% and 90% relative humidity (RH) and 27 °C. A standard soil block decay test using the brown-rot fungus *Gloeophyllum trabeum* was performed and weight loss calculated.

Two possible mechanisms have been proposed to explain the resistance of attack of brown-rot fungi on chemically modified wood. One involves the lowering of the cell wall moisture level below that needed for fungal attack. The second involves changing the configuration and conformation of the substrates by modification in such a way that the enzymes can not recognize the substrate. The data presented in this paper indicates that lowering the cell wall moisture level is the major mechanism.

Key words: Acetylation, brown-rot fungus, moisture, decay.

INTRODUCTION

It is well documented that brown-rot fungi degrade the carbohydrate polymers in the cell wall and in the early stages of attack, the degree of polymerization (DP) of the carbohydrate polymers decreases rapidly. This loss in DP results in strength losses before there is very much weight loss. As the weight loss increases, the carbohydrate polymers are badly degraded. This is consistent with the theory that the first mode of attack is an enzymatic attack on the hemicelluloses generating a chemical oxidation system (H_2O_2, Fe^{+++}) that then attacks the carbohydrate polymer matrix giving rise to strength losses. This oxidation system then provides the energy source for the

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generation of β–glucosidases(indo- and exo-cellulases) that ultimately results in weight loss.

What is not so well understood is why chemical modification of wood results in increased resistance to attack by brown-, white-, and soft-rot fungi. As the level of modification increases, resistance to fungal degradation increases. Earlier research has shown that acetylated composites in a fungal cellar with brown-, white-, and soft-rot fungi and tunneling bacteria resisted attack as the level of acetyl content increased. Control blocks were destroyed in less than 6 months while flakeboards made from acetylated furnish above 16 weight percent gain (WPG) showed no attack after 1 year (Table 1) (Nilsson et al. 1988, Rowell et al. 1987, Rowell 2005). This data shows that no attack occurs until swelling of the wood occurs. This fungal cellar test was continued for several additional years with no attack above 16 WPG.

Table 1. Fungal cellar tests of aspen flakeboards made from control and acetylated flakes.[1]

WPG	Rating at intervals (months)[3]									
	2	3	4	5	6	12	24	36	72	144
0	S/2	S/3	S/3	S/3	S/4	--	--	--	--	--
7.3	S/0	S/1	S/1	S/2	S/3	S/4	--	--	--	--
11.5	0	0	S/0	S/1	S/2	S/3	S/4	--	--	--
13.6	0	0	0	0	S/0	S/1	S/2	S/4	--	--
16.3	0	0	0	0	0	0	0	0	0	0
17.9	0	0	0	0	0	0	0	0	0	0

[1]Nonsterile soil containing brown-, white-, and soft-rot fungi and tunneling bacteria. [2]Flakeboards bonded with 5 percent phenol-formaldehyde adhesive. [3]Rating system: 0 = no attack; 1 = slight attack; 2 = moderate attack; 3 = heavy attack; 4 = destroyed; S = swollen.

More evidence that the moisture content of the cell wall is critical before attack can take place was done on chemically modified wood (Ibach and Rowell 2000, Ibach et al. 2000). Leached and un-leached southern pine was reacted with acetic anhydride, propylene and butylenes oxides and placed in a soil block test using a brown-rot fungi. Specimens with an acetyl WPG above 19 were resistant to attack.

The purpose of the present research was to determine the equilibrium moisture content of both control and acetylated southern pine wood and fibers, degrade them in a laboratory soil block test and correlate the decrease in cell wall moisture content with decay resistance.

MATERIAL AND METHODS

Acetylation of Wood

Southern pine solid wood (2.5 cm3) and fibers were acetylated as previously described (Rowell et al. 1986). The reaction was carried out for various lengths of time to give acetyl weight gain on solid wood of 5, 12, 14, and 19 and fibers of 5, 9, 13, and 15. Three samples at each weight gain were prepared. The weight percent gain (WPG) was determined using wood oven-dry weight before and after acetylation.

Equilibrium Moisture Content (EMC)

Oven-dry specimens were placed in constant humidity rooms at 30%, 65% and 90% relative humidity (RH) and 27 °C. After 21 days the specimens were weighed to determine the EMC. Previous work showed that EMC of control and acetylated samples was reached at 14 days (Rowel1 and Rowell 1989). Three samples at each WPG were done and the results averaged.

Soil Block Test

The ASTM D 1413 standard soil block test was performed on both solid wood and fiber specimens (ASTM 1976). Untreated controls and acetylated solid wood and fiber (0.5g) were exposed to the brown-rot fungus *Gloeophyllum trabeum.* Solid wood specimens were removed from test in 12 weeks and fiber specimens in 9 weeks. The extent of decay was determined as oven dry weight loss.

RESULTS

Table 2 shows the results of the moisture sorption at 30%, 65% and 90% RH and the weight loss after the soil block test. In the solid wood specimens, the control sample lost 65.8% weight and had an EMC at 90% of 20.2%. As the WPG of acetyl increased, the EMC decreased as did the weight loss due to fungal attack. At 19 WPG, the weight loss was only 5% and the EMC at 90% RH was 8.6%.

Table 2. Equilibrium moisture content of southern pine before and acetyl content before and after attack by brown-rot fungus.

Solid Wood				
WPG	EMC at:			Weight loss %
	30% RH	65% RH	90% RH	
0	4.2	9.4	20.2	65.8
5	2.9	7.0	16.5	58.8
12	2.4	5.2	13.0	44.9
14	1.8	4.6	11.4	35.6
19	1.1	3.7	8.6	5.0

Fiber				
0	2.9	7.9	12.4	51.7
5	2.2	6.2	10.1	26.5
9	1.6	5.2	8.5	5.9
13	1.0	3.8	6.4	1.4
15	0.9	3.5	5.9	0.7

Table 2 also shows the results of the moisture sorption weight loss after the soil block test for southern pine fiber. The EMC for the control fiber was much lower than for the solid wood possibly indicating surface extractives or resin. The control sample has an EMC of 12.4% and a loss of 51.7% due to fungal attack. As with solid wood, as the WPG due to acetylation increased, the weight loss due to fungal attack decreased. At a WPG of 9, the EMC was 8.5% and the weight loss was only 5.9%. At 13 and 15 WPG, the weight loss due to fungal attack was less than 2%.

DISCUSSION

The decrease in EMC for a given WPG is greater in wood fiber as compared to solid wood. This would indicate that there are more accessible hydroxyl groups in fiber than in solid wood. Acetylation of both solid wood and wood fiber results in a decrease in EMC and an increase in resistance to attack by a brown-rot fungus. The WPG needed to protect wood fiber from brown-rot fungi is much less required to protect solid wood. This would also indicate that the hydroxyl groups needed to be substituted for fungal protection are more accessible in fibers as compared to solid wood.

CONCLUSIONS

Acetylation of both solid wood and wood fibers results in a lowering of the EMC and an increase in resistance to attack by a brown-rot fungus. This presents more data to support the theory that the mechanism of fungal resistance is the lowering of the moisture content in the cell wall. It is also possible, however, that the replacement of hydroxyl groups with acetyl groups interferes with the specific enzyme-substrate recognition mechanism. More research is needed to make a definite conclusion.

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