Towards the Development of Accelerated Methods for Assessing the Durability of Wood Plastic Composites

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The markets for wood plastic composite (WPC) decks have experienced rapid growth over the past five years, although their overall share of the decking market remains small (Clemons, 2000, 2002; Morton et al., 2003). Among the many selling points for WPCs is that they are inherently more resistant to biodeterioration than untreated wood; however, a number of laboratory and field studies have shown that the wood in these materials remains susceptible to decay (Morris and Cooper 1998; Mankowski and Morrell, 2000; Laks and Verhey, 2003; Clemons and Ibach, 2002; Ibach and Clemons, 2002; Ibach et al., 2003; Pendleton et al., 2002; Silva et al., 2002; Verhey et al., 2001, 2002; Simonsen et al., 2002). While these reports indicate that decay does occur, they have also shown that the rates are generally much slower than found with untreated wood of the same species. A major contribution to this reduced decay rate is the inherent moisture resistance of the WPC (Naghipour, 1996; Schmidt, 1993). While moisture levels do eventually reach the point at which biological attack is possible, the wetting rate is slow and most of the moisture is confined to a zone within 5 mm of the WPC surface (Wang and Morrell, in press).

The issue of moisture distribution in relation to biological attack is of little concern in field tests, owing to the longer time periods associated with these trials that can allow for moisture sorption (Verhey et al., 2003). However, the time required to absorb a sufficient amount of moisture in short term laboratory trials can occupy a high percentage of total test time, markedly reducing the potential for biological attack. In general, North American WPC producers have evaluated the durability of their products using modifications of the American Wood Preservers' Association Standard E10 Soil Block test (AWPA, 2001) or American Society for Testing Materials (ASTM) Standards for evaluating natural durability or preservative performance (ASTM, 2003a,b). These methods expose cubes or wafers of the test material to a pure culture of a test fungus growing on a wood feeder strip on sterile soil. Weight losses, in tests of solid sapwood, typically range from 20 to 65% over a 12 week test period, depending on the fungus and wood species. In contrast, similar tests with WPC blocks produce wood weight losses of only 5 to 10%. These low weight losses make it difficult to delineate performance differences between various WPCs and highlight the need for test methodologies that are more appropriate for testing WPC durability.

In this report, we describe a series of trials to develop an accelerated laboratory test for assessing WPC durability. In the first phase, a variety of test methodologies were examined. These results were used to select the most aggressive test, then conditions in this method were varied to determine if further improvements were possible. Finally, we examined the effects of material variables such as wood species and specimen thickness, on the test method.

MATERIALS AND METHODS

Pellets containing a 60/40 ratio of ground sugar maple (*Acer saccharum*) or pine (*Pinus* sp.) and high density polyethylene (HDPE) were obtained from North Wood Plastics, Inc (Sheboygan Wisconsin. The pellets were placed in a 150 x 150 x 0.5 mm mold which was heated to 180°C (350°F) and pressed for 10 minutes at 1500 KPa, then cooled at room temperature to about 100°C (180°F). Additional wafers were produced for the final test that were 2.5, 5.0, and 8.0 mm thick. After cooling, the resulting samples were cut into wafers measuring 10 x 20 x 0.5 mm thick. Sugar maple (*A. saccharum*) wafers, cut to the same size, were used as controls to ensure that conditions in the incubation chambers were suitable for fungal decay of wood.

All samples (WPCs and maple wafers) were oven-dried at 104°C for 24 hours to remove water, weighed to the nearest 0.0001 grams, and submerged in distilled water for 48 hours to introduce enough water to allow fungal attack. The samples were then sterilized by heating at 121°C for 20 minutes. In most cases, only WPC's containing maple were tested except for the final tests of wafer thickness.

Test Fungi: The brown-rot fungi *Gloeophyllum trabeum* (Pers. Ex. Fr.) Murr. (Isolate Madison 617), *Coniophora puteana* (Schum:Fr.) Karst (Isolate Madison 515) and *Postia placenta (*Fr.) M. Larsen & Lomb. (Isolate Madison 698), and the white-rot fungi *Irpex lacteus* (Fr:Fr) Fr. (Isolate HBB-7328) and *Trametes versicolor* (L:Fr) Pilat (Isolate R105) were maintained on 1% malt extract agar (MEA) in petri dishes until needed.

Production of Inoculum: Fungi were taken from the maintenance cultures (above) and then grown for 21 days either in petri dishes containing 1% MEA or in 500 ml Erlenmeyer flasks containing 150 ml of 1% malt broth. The liquid fungal inoculum was prepared by placing two, 4 mm-diameter discs in Erlenmeyer flasks containing 150 ml of 1% malt broth. The liquid cultures were incubated under stationary conditions for 21 days at room temperature (22-25°C). After incubation, the contents of the flasks containing a given fungus were poured through a sterile Buchner funnel with no filter paper. The mycelial mass caught in the funnel was resuspended in 80 ml of sterile distilled water and blended at high speed for 30 seconds. The macerated mycelia were then poured into a sterile 100 ml squeeze bottle for inoculation of either culture media or samples.

Incubation chambers and test temperatures: Incubation chambers were either 115-mm diameter petri dishes, 150 ml Erlenmeyer flasks, or 454-ml glass jars. The petri dishes containing one of the following: 1% malt extract agar (MEA), 1% potato dextrose agar (PDA), glucose amended basal salts, soil (direct exposure and sandwich) or vermiculite were inoculated with 4 mm agar plugs cut from the actively growing edges of the maintenance cultures. The Erlenmeyer flasks contained either 1% malt extract broth, maple sawdust, or red alder sawdust and were incubated with the liquid inoculum. The glass jars (454 ml French squares) contained garden soil. All chambers were incubated at 28 °C except for the liquid media tests, which were incubated at room temperature (22-25 °C).

Samples exposed in the initial screening tests were incubated for up to 17 weeks. The basal salts tests were carried out after the first set of the screening tests, and because of the promising results obtained in the initial tests, a shorter exposure period of 12 weeks was used with sampling every 3 weeks. Samples in the optimization and soil block tests were also exposed for 12 to 15 weeks.

Moisture content and weight loss sampling: Samples were removed and adhering mycelium, agar, soil, sawdust or vermiculite was carefully removed. Samples were weighed (nearest 0.0001 g), oven-dried for 24 hrs at 104°C and weighed again to determine both moisture content and weight loss.

Initial Evaluations of Test Methods: In the initial phase of these tests the suitability of a number of different methods for enhancing fungal attack of wood-based materials was assessed.

For agar media tests, petri dishes received 20 ml of 1.0% malt extract agar. Once this media solidified, a u-shaped glass rod was placed in the agar surface, one of the test fungi was inoculated, and 10 test wafers were placed on these rods in each dish. Half of the wafers within any dish were placed so that the specimens were above the agar, while the remainder were placed so that one end was in direct contact with the agar to encourage moisture uptake. Similar plates were prepared with a basal salts medium amended with varying levels of nitrogen and glucose to produce carbon:nitrogen ratios of 100:1 or 500:1.

Wafers exposed to malt extract broth . m,aple sawdust or alder sadust wereplaced in the 150 ml ehlenmeyer flask. In the case of the sawdust, the wafers were partially forced into each the media to encourage moisture uptake, then the test fungus was inoculated by placing several agar plugs as described previously.

In addition, a second inoculation method was employed wherein twenty decay chambers were prepared by placing 17 g of garden soil in each petri dish along with distilled water to raise the moisture content of the soil to 70%. Sets of five petri dishes, each one containing 20 wood wafers (10 x 20 x 0.5 mm), were sterilized and inoculated with 4 ml of liquid inoculum of one of the three test fungi. The remaining five petri dishes were left uninoculated to serve as controls. The decay chambers were sealed with paraffin film and incubated at 28 °C until mycelia covered nearly all the wafers. These fungal colonized wafers were then used to assemble ten sandwiches with two fungal inoculated wafers surrounding one WPC sample. The three samples (two fungal colonized and the WPC) were held together with a paper clip and these assemblies were placed in moistened vermiculite in petri dishes.

Ten sets of six liquid incubation chambers were prepared by placing two 4 mm-diameter agar discs of each test fungus from the maintenance culture into 150 ml Erlenmeyer flasks containing 50 ml of 1% malt extract broth. Two additional sets of six incubation decay chambers were left uninoculated to serve as controls. Five sets of six incubation chambers inoculated with a given fungus (one half of the total incubation chambers), and one non-fungal exposed control set were incubated under either stationary conditions or in a rotary shaker at laboratory room temperature

(22-25 °C) for 21 days. Once the fungus had grown for 21 days, ten WPC samples were placed in each flask and incubated at room temperature (22°C to 25°C).

The various decay chambers were incubated for periods of 4 to 17 weeks, then ten wafers exposed to given fungus were removed to determine moisture content and wood weight loss. A minimum of 50 wafers were tested per fungus per decay configuration.

The results from the first tests suggested that the malt extract agar plates produced excellent weight losses for most fungi and were by far the simplest to establish. However, some fungi were less active on this media, implying that other media might be more useful. In the second phase of the study, petri dishes containing 0.5, 1.0 or 1.5% MEA or potato dextrose agar (PDA) were prepared as described earlier and then received the WPC test pieces along with fungal inoculum. In addition, WPC wafers were exposed in a soil block test following procedures described in AWPA Standard E10 (AWPA, 2004) except that the 19 mm square test blocks were replaced by the 10x20x0.5 mm thick WPC samples. The blocks in the MEA or PDA as well as those in the soil bottles were incubated at 28°C for 3 to12 weeks. Ten WPC wafers were removed at each time point for each media/fungal combination. These wafers were weighed and processed as described earlier.

Effect of WPC wafer thickness: WPCs have markedly different moisture sorption characteristics compared to the wood from which they are made (Wang and Morrell, 2004). One important property in a WPC decay test is specimen thickness, since thicker samples are likely to sorb

moisture more slowly and will therefore attain conditions suitable for fungal growth more slowly than thinner samples. The effect of WPC wafer thickness on resistance to fungal attack was assessed by producing WPCs composed of 60% by volume of either maple or pine using procedures described earlier. Specimens were compression-molded to produce wafers that were 0.5, 2.5, 5 or 8 mm thick. These wafers were then exposed to the three test fungi on glass rods over 1% MEA as described earlier. Moisture content and weight loss were assessed at 3-week intervals over 15 weeks on a wood weight basis as described earlier.

Statistical Analysis: The data were subjected to an Analysis of Variance (ANOVA) and General Linear Models (GLM) (SAS, 2002). Mean values were compared using Duncan's multiple-range test ($\forall$=0.5). In addition, the relationship between final moisture content was regressed against wood weight loss regardless of fungus and these results were plotted to assess the relationship between these two variables.

RESULTS AND DISCUSSION

Initial Screening Tests: Average moisture contents of the maple WPC wafers ranged between 21.8 to 39.3% four weeks after introduction of the wafers (Table 1; Figure 1). Moisture contents then became more variable among the various decay chamber types over the next 17 weeks (Figure 1), reflecting differential moisture holding capacities of the test media as well as varying degrees of fungal activity. For example, MCs in vermiculite ranged from 29% for *T. versicolor*

to 74% for *G. trabeum* at the end of the test period. Moisture conditions were suitable for fungal attack for at least 12 weeks under all test conditions except the liquid media.

Weight losses in the absence of a fungus were negligible, regardless of decay chamber (Table 1). Wood weight losses in the WPC samples exposed to the test fungi generally increased over the 17 week incubation period, except for the samples incubated in liquid cultures. Weight losses at the end of the incubation period often differed little from those found after 14 weeks, suggesting that the fungus had consumed the available wood and was unable to take advantage of prolonged incubation.

The absence of substantial weight losses in the liquid media was perplexing because all three of the test fungi grew well in the flasks. Liquid cultures were originally included because of observations in preliminary tests suggesting that wood attack occurred without substantial hyphal penetration into the WPC matrix. This led us to suspect that the degradation was primarily due to attack by enzymes diffusing into the WPC matrix. If true, then liquid cultures would allow for aggressive growth and enzyme production of the test fungi. These enzymes would then act upon wood particles on the WPC surface. This clearly did not occur under our test conditions. Although moisture levels were not excessively high in these samples, it appears that the fungi were unable to colonize the submerged samples. The lack of attack may reflect limited oxygen availability in the submerged culture (Scheffer and Livingston, 1937), although this parameter was not assessed in the chambers.

Weight losses with *G. trabeum* were highest in vermiculite chambers followed by those in MEA. Weight losses in the remaining chambers were less than 10% after 17 weeks, suggesting that these chambers did not provide suitable conditions for attack by this fungus. Weight losses with *P. placenta* were highest in the alder sawdust chambers, followed by the MEA and vermiculite chambers. Weight losses associated with this fungus were also elevated in the maple sawdust chambers. Weight losses in WPCs exposed to *T. versicolor* were highest in the soil chamber, followed closely by the MEA chambers and the alder sawdust. Weight losses in *T. versicolor* exposed wafers were also elevated in the maple sawdust and soil sandwich tests, while those exposed in vermiculite chambers were negligible. Each fungus has specified moisture ranges that are optimal for attacking solid wood (Zabel and Morrell, 1992; Ammer, 1964; Eaton and Hale, 1992). For example, *T. versicolor* is usually presumed to require more moisture than either of the brown rot fungi. This relationship is illustrated by the higher weight losses associated with this fungus in MEA and soil systems which, coincidentally, were associated with the highest wood moisture contents at the end of the test period (Figure 1).

The results from these preliminary trials suggested that the MEA system produced the most consistently high weight losses across the three species. In addition, these chambers were relatively easy to establish in large numbers and the conditions in each chamber could be controlled by careful attention to media preparation. The sawdust, soil and vermiculite chambers, while useful for certain material/fungus combinations were much more labor intensive to prepare and experienced moisture fluctuations upon prolonged exposure that made them less reproducible. Based upon these results, agar plate systems were selected for further study.

Comparisons between soil block tests and agar tests: Moisture contents in WPC wafers exposed in soil block tests increased steadily over the 12-week incubation period, ranging from 29.8% MC in the non-fungus inoculated control to 64.8% for the wafers exposed to *P. placenta* for 12 weeks (Table 2). Weight losses in the soil block chambers ranged from 25% with *T. versicolor* to 26.1% for *G. trabeum*. These weight losses are indicative of substantial attack of the wood in the WPC matrix and indicate that soil block test procedures were suitable for assessing the WPC wafers.

Moisture levels in WPC wafers in the two agar systems ranged from 30 to 95% after 12 weeks of fungal exposure, while moisture levels tended to be lower in non-fungal exposed controls (Table 4; Figure 2). The elevated moisture levels in fungal exposed wafers may reflect hyphal-mediated moisture uptake.

Weight losses in MEA plates were higher than those in PDA plates when wafers were exposed to *G. trabeum* (Table 4). Both PDA and MEA are relatively nutrient-rich media. Excess sugar can affect decay by brown rot fungi, but this was not evident with *P. placenta* which produced similar weight losses on both media (Highley, 1973). In addition, increasing concentrations of either media had little effect on weight losses by *P. placenta*. Conversely, *T. versicolor* produced consistently higher weight losses on PDA and these losses increased with media concentration.

Comparisons between soil block and MEA or PDA as support media for the decay tests suggested that weight losses did not differ significantly between the soil block tests and at least one media condition for each of the test fungi (Table 3). The results suggest that at least two different media might be needed to adequately evaluate the decay resistance of WPCs against a range of fungi. In addition, elevated nutrient levels may be required to produce acceptable weight losses with some fungi.

While MEA and PDA were suitable media for the decay tests, both are considered as undefined media whose contents can vary with supplier and even batch. A more reproducible standard would use a defined media whose constituents could be more easily reproduced by different laboratories. Attempts to use a basal salt media amended with varying levels of glucose produced mixed results (Table 5). Moisture contents of WPCs in these media were much lower than those found with either MEA or PDA. These lower MCs probably reflect the reduced fungal growth associated with these media. The only media/fungus combinations that produced weight losses above those found with non-fungal exposed controls were found with *T. versicolor*. However, even these weight losses were generally lower than those found with PDA. The results also suggest that higher nitrogen levels negatively affected weight losses. The 100:1 CN ratio produced much lower weight losses at both 1.5 and 2.5% glucose. Nitrogen is generally limiting in wood, and excess nitrogen can also influence fungal attack (Zabel and Morrell, 1992). Clearly, the defined media was not broadly suitable for inducing substantial weight losses in the WPC tested.

Effect of Specimen Thickness on Fungal Attack: Moisture contents of WPC samples composed of sugar maple tended to sorb moisture from the agar relatively quickly, although moisture levels were generally lower in specimens thicker than 0.5 mm (Figure 3). Moisture levels also tended to be much lower in non-fungal exposed controls. Moisture levels in WPC wafers composed of pine were sharply lower than those in maple WPC and there was little difference in MC between WPCs of varying thicknesses (Figure 3). The reason for the lower MCs in the pine WPCs is unclear although the resins in the pine sawdust may provide some water repellency that is absent in the maple WPCs.

Weight losses in maple WPCs increased steadily over the first 12 weeks of exposure, then became more variable (Table 6). The highest weight losses on this material were found with the two brown rot fungi, although *T. versicolor* also produced substantial losses. Weight losses declined by 50% or more as specimen thickness increased from 0.5 to 2.5 mm then changed only slightly with further thickness increases. Weight losses in pine WPCs were extremely low for all thickness and fungal combinations, most probably reflecting the low moisture contents achieved in these materials (Table 7). Weight losses for 0.5 mm thick WPCs composed of pine averaged only 5.9 and 8.8% for *G. trabeum* and *P. placenta*, respectively, after 15 weeks of exposure. These levels are clearly unsuitable for evaluating the comparative decay resistence of materials that may be further amended with biocides. They do, however, highlight the potential for varying wood species in a WPC to produce desirable properties such as resistance to moisture uptake.

Role of Moisture in WPC Decay: Throughout these tests, it was apparent that moisture uptake was crucial for enhancing fungal attack of the WPC. Placing the test wafer in direct contact with the agar sharply reduces weight losses in conventional agar block tests of solid wood, but it produced rapid moisture sorption in WPCs containing maple, leading to increased fungal attack. Attempts to use other media such as soil, vermiculite or defined media produced more variable moisture uptake and, consequently, less fungal attack. These effects were clearly illustrated when moisture content in the 0.5 mm thick WPC wafers at the end of the test was plotted against wood weight loss for all of the tests and time periods (Figure 4). Clearly, methods that encourage moisture uptake must be an essential element of any WPC durability test. Limited attempts to encourage moisture uptake through vacuum/pressure cycles produced little noticeable improvement in moisture levels (Freitag and Morrell unpublished). Test configurations that allow for rapid surface sorption and, presumably, subsequent diffusion inward appear to produce the highest, most consistent moisture regimes.

CONCLUSIONS

Malt extract and potato dextrose agar decay chambers produced weight-loss results that were equal to or greater than those found using the traditional soil block tests, provided the wafers were thin enough to allow for rapid moisture uptake. The agar plates are much easier to establish and monitor, and occupy less incubator space. In addition, the potential effects of changes in water holding capacity due to soil changes were avoided using the agar systems. The ability to test larger, more representative WPC samples under laboratory conditions was largely limited by

moisture uptake. While further studies to encourage more rapid moisture sorption in thicker specimens might improve test results, it appears that current decay tests should be limited to thin specimens to encourage both moisture sorption and fungal attack. Further tests to better understand the differential moisture behavior of WPCs composed of maple or pine are recommended so that test procedures can be developed that are more suitable for inducing substantial weight losses in a broader range of WPCs.

LITERATURE CITED

American Society for Testing and Materials (ASTM). 1999. Standard D2017-81 (1994). Standard Test Method for Accelerated Laboratory Test of Natural Decay Resistance of Woods. In; Annual book of Standards, Vol 4.10. American Society for Testing and Materials, West Conshohoken, PA.

American Society for Testing and Materials (ASTM). 1999. Standard ASTM D-1413 76 (reapproved 1994). Standard test method for wood preservatives by laboratory soil-block cultures. In; Annual book of Standards, Vol 4.10. American Society for Testing and Materials, West Conshohoken, PA. pp. 209-215.

American Wood Preservers Association (AWPA). 2004. Standard E10-91. Standard method of testing wood preservatives by laboratory soil-block cultures. American Wood Preservers Association (AWPA). Book of Standards 2004. Selma, Alabama.

Ammer, V. 1964. On the connection between moisture content and fungal decay in wood. Holz als Roh-und Werkstoff 22(2):47-51.

Clemons, C. M. 2000. Wood fiber-plastic composites in The United States – History and current and future markets. 3rd International Wood and Natural Fibre Composites Symposium. Kassel, Germany. pp. 1-1 to 1-7.

Clemons, C. M. 2002. Wood-plastic composites in the United States. The interfacing of two industries. Forest Products Journal 52(6):10-18.

Clemons, C. M. and R. E. Ibach. 2002. Laboratory tests on fungal resistance of wood filled polyethylene composites. Conference proceedings. Volume II. Materials. ANTEC. Annual conference. May 5-9. Society of Plastic Engineers. San Francisco, CA. pp. 2219-2222.

Eaton, R. A. and M. D. C Hale. 1993. Wood decay, pests and protection. First Edition. Chapman & Hill. London. 546 p.

Freitag, M. and J. J. Morrell. 1990. Wood sandwich test of potential biological control agents for basidiomycetous decay fungi. Material und Organismen 25(1):63-70.

Highley, T. L. 1973. Influence of carbon source on cellulase activity of white-rot and brown-rot fungi. Wood and Fiber Science 5:50-58.

Ibach, R. and C. M. Clemons. 2002. Biological resistance of polyethylene composites made with chemically modified fiber or flour. In proceedings, The 6th Pacific Rim Bio-based Composites Symposium & Workshop on the Chemical Modification of Cellulosics. Portland, OR. pp 574-583.

Ibach, R. E., Clemons, C. M. and N. M. Stark. 2003. Combined UV and water exposure as a preconditioning method in laboratory fungal durability testing. 7th International Conference on Woodfiber-plastics Composites. The Forest Products Society. Madison, WI. http://www.forestprod.org/wpc03ibach.pdf. (In press).

Mankowski, M. and J. J. Morrell. 2000. Patterns of fungal attack in wood plastic composites following exposure in a soil block test. Wood and Fiber Science 32(3):340-345.

Morris, P.I. and P. Cooper. 1998. Recycled plastic/wood composite lumber attacked by fungi. Forest Products Journal 48(1):86-88.

Morton, J., Quarmley, J. and L. Rossi. 2003. Current and emerging applications for natural and woodfiber composites. Proceedings 7th International Conference on woodfiber-plastic composites. May 2003. Forest Products Society. Madison, WI. http://www.forestprod.org/wpc03morton.pdf (In press).

Naghipour, B. 1996. Effects of extreme environmental conditions and fungal exposure on the properties of wood-plastic composites. Master of Science. University of Toronto. Toronto, Canada. 79 p.

Pendleton, D. E., T.A. Hoffard, T. Addock, B. Woodward, and M. P. Wolcott. 2002. Durability of an extruded HDPE/wood composite. Forest Products Journal 52(6):21-27.

Schmidt, E. L. 1993. Decay testing and moisture changes for a plastic-wood composite. Proceedings American Wood Preservers' Association 89:108-109 (Abstr.).

SAS Institute Inc. 2002. Statistical Analysis Systems. Release 8.02. SAS Institute Inc., Cary, NC.

Scheffer, T. C. and B. E. Livingston. 1937. Relation of oxygen pressure and temperature to growth and carbon production in the fungus *Polystictus versicolor*. American Journal of Botany 24:109-119.

Sexton, C. M., Forsyth, P. G. and J. J. Morrell, 1993/1994. A comparison of agar exposure and vermiculite burial methods for preparing basiomycete-colonized wood. Material und Organismen 28 (1):39-46.

Silva G., J. A., Freitag, C., Morrell, J. J. and B. L. Gartner. 2002. Effect of fungal attack on creep behavior and strength of wood plastic composites. The Sixth International Conference on Woodfiber-Plastic Composites. Proceedings. The Forest Products Society. Madison, WI. pp. 69-72.

Simonsen, J., Freitag, C. M. and J. J. Morrell. 2002. The effect of wood-plastic ratio on the performance of borate biocides against brown-rot fungi. The Sixth International Conference on

Woodfiber-plastic Composites. Proceedings. The Forest Products Society. Madison, WI. pp. 69-72.

Verhey, S., Laks, P. and D. Richter. 2001. Laboratory decay resistance of woodfiber/ thermoplastic composites. Forest Products Journal 51(9):44-49.

Verhey, S. A., Laks, P. E. and D. L. Richter. 2002. The effect of composition on the decay resistance of model woodfiber-thermoplastic composites. The Sixth International Conference on Woodfiber-plastic Composites. Proceedings. The Forest Products Society. Madison, WI. pp. 79-86.

Verhey, S., Laks, P. E., Richter, D. L., Keranen, E. D. and G. M. Larkin. 2003. Use of field stakes to evaluate the decay resistance of woodfiber-thermoplastics composites. Forest Products Journal 53(5):67-74.

Verhey, S.A. and P.E. Laks. 2002. Wood particle size affects the decay resistance of wood fiber/thermoplastic composites. Forest Products Journal 52(11/12):78-81.

Wang, W. and J. J. Morrell. 200X. Water sorption characteristics of two wood/plastic composites. Forest Products Journal (In press).

Zabel, R. A. and J. J. Morrell. 1992. Wood microbiology: decay and its prevention. Academic Press Inc., San Diego, CA. 474 p.

Are these pine or maple WPCs??

Table 1. Moisture contents (MC) and weight losses (WL) of the wood component in a maple WPC at selected times following exposure to *G. trabeum, P. placenta*, or *T. versicolor* in various types of decay chambers.

Fungi	Decay chambers	Exposure Period [1]						
		4 weeks		8 weeks	11 weeks	14 weeks	17 weeks	
		MC (%)	WL (%)	WL (%)	WL (%)	WL (%)	MC (%)	WL (%)
G. trabeum	liquid (shaker)	28.1 (2.3)	0.6 (0.2)	-3.2 (1.3)	-1.1 (1)	0.1 (1.8)	ND[2]-	ND[2]-
	liquid (stationary)	31.9 (2.3)	1.6 (0.8)	-0.1 (1.0)	-2.3 (1.2)	2.7 (1.4)	ND[2]-	ND[2]-
	MEA (plates)	39.3 (4.9)	7.7 (3.2)	12.7 (3.7)	11.0 (9.3)	31.1 (7.4)	54.5 (7.5)	25.1 (7.3)
	maple sawdust	32.7 (1.0)	2.1 (0.7)	2.3 (0.7)	2.3 (1.5)	3.8 (1.2)	26.0 (1.2)	3.0 (1.4)
	alder sawdust	33.6 (1.5)	3.2 (0.9)	1.2 (0.7)	3.0 (1.0)	3.6 (0.9)	21.0 (1.6)	1.2 (0.8)
	soil (sandwich)	35.1 (1.2)	5.5 (1.3)	7.3 (1.9)	6.3 (2.5)	8.8 (2.0)	34.3 (2.5)	7.3 (4.7)
	soil (plates)	32.4 (9.2)	2.8 (2.6)	7.8 (3.8)	14.5 (3.9)	6.0 (1.9)	31.3 (1.8)	6.5 (3.7)
	vermiculite	30.7 (1.9)	4.6 (1.6)	18.4 (4.7)	32.3 (4.8)	41.6 (9.2)	74.4 (18.1)	47.4 (11.0)
P. placenta	liquid (shaker)	29.4 (2.3)	0.9 (0.5)	-1.6 (1.6)	-1.7 (0.4)	-0.3 (1.1)	ND[2]-	ND[2]-
	liquid (stationary)	26.8 (5.7)	0.7 (0.3)	-0.5 (0.9)	-0.4 (1.1)	1.9 (2.1)	ND[2]-	ND[2]-
	MEA (plates)	33.6 (2.9)	3.3 (1.8)	10.9 (3.2)	21.2 (6.8)	16.5 (6.8)	8.6 (1.0)	21.2 (6.0)
	maple sawdust	35.1 (3.0)	4.7 (1.6)	11.9 (3.4)	20.4 (3.2)	29.9 (4.1)	11.9 (1.3)	16.7 (5.3)
	alder sawdust	34.2 (2.7)	4.6 (1.4)	13.0 (3.1)	26.1 (6.3)	32.6 (4.7)	10.9 (1.0)	30.4 (6.0)
	soil (sandwich)	31.9 (1.4)	1.6 (0.6)	3.6 (1.6)	4.9 (1.8)	3.3 (2.3)	27.4 (1.3)	8.7 (4.4)
	soil (plates)	30.6 (1.3)	1.4 (0.5)	2.4 (1.6)	2.3 (1.4)	1.9 (0.6)	32.2 (1.4)	2.8 (1.2)
	vermiculite	30.5 (2.5)	1.9 (1.2)	6.1 (7.2)	11.2 (3.1)	18.5 (6.5)	46.6 (6.1)	21.5 (5.5)

[1] Average moisture contents and weight losses are the means of ten specimens per treatment. Values in parentheses are standard deviations.
[2] ND- not determined.

Table 1. Continued.

Fungi	Decay chambers	Exposure Period [1]						
		4 weeks		8 weeks	11 weeks	14 weeks	17 weeks	
		M C (%)	W L (%)	W L (%)	W L (%)	W L (%)	M C (%)	W L (%)
T. versicolor	liquid (shaker)	30.2 (2.1)	0.8 (0.5)	-0.3 (1.6)	0.6 (1.2)	-0.2 (1.1)	ND[2]-	ND[2]-
	liquid (stationary)	29.3 (1.8)	1.9 (0.6)	0.0 (2.1)	1.9 (2.1)	-0.1 (2.4)	ND[2]-	ND[2]-
	MEA (plates)	33.5 (2.1)	3.3 (1.0)	9.7 (2.3)	17.4 (1.7)	21.1 (4.0)	58.1 (10.7)	30.2 (5.6)
	maple sawdust	33.6 (1.7)	3.6 (0.7)	5.2 (1.2)	9.2 (2.0)	10.1 (2.8)	36.3 (4.8)	16.2 (3.4)
	alder sawdust	32.9 (1.8)	4.3 (0.8)	6.2 (1.2)	9.6 (1.5)	10.5 (2.2)	32.3 (6.4)	23.8 (5.7)
	soil (sandwich)	34.3 (1.8)	3.9 (1.1)	5.7 (2.9)	13.0 (4.8)	13.7 (4.0)	38.8 (4.9)	17.0 (5.5)
	soil (plates)	31.0 (0.9)	1.2 (0.7)	9.3 (5.6)	16.2 (3.5)	31.6 (4.8)	43.8 (7.6)	31.9 (8.6)
	vermiculite	27.1 (1.7)	1.4 (0.7)	1.4 (1.1)	1.8 (1.3)	2.5 (1.5)	29.0 (1.5)	1.6 (1.4)
control	liquid (shaker)	26.5 (1.8)	0.0 (0.5)	-0.2 (0.6)	-5.5 (1.9)	ND[2]-	ND[2]-	ND[2]-
	liquid (stationary)	25.9 (0.9)	1.1 (0.8)	-0.1 (0.4)	-3.0 (1.3)	ND[2]-	ND[2]-	ND[2]-
	MEA (plates)	29.2 (2.4)	0.8 (0.6)	-0.3 (0.4)	1.2 (0.7)	ND[2]-	10.5 (1.5)	-0.3 (1.0)
	maple sawdust	28.1 (1.9)	1.2 (0.7)	1.6 (0.2)	0.7 (1.2)	0.9 (1.9)	15.9 (0.7)	1.8 (0.5)
	alder sawdust	31.2 (1.9)	0.9 (0.5)	2.3 (0.8)	1.8 (0.9)	1.7 (0.8)	27.3 (1.7)	1.4 (0.6)
	soil (sandwich)	33.6 (1.3)	1.3 (0.5)	1.1 (0.6)	0.4 (0.6)	0.9 (0.6)	28.4 (1.7)	0.6 (0.6)
	soil (plates)	21.8 (1.2)	1.8 (0.6)	1.5 (0.7)	1.9 (2.1)	1.1 (0.6)	13.0 (0.5)	0.9 (0.6)
	vermiculite	24.9 (1.7)	1.5 (1.1)	1.3 (1.0)	2.0 (0.7)	1.5 (1.2)	22.1 (3.2)	1.9 (0.8)

[1] Average moisture contents and weight losses are the means of ten specimens per treatment. Values in parentheses are standard deviations.
[2] ND= Not determined.

Table 2. Moisture contents (MC) and weight losses (WL) of the wood component in a maple WPC exposed for 3 to 12 weeks to *G. trabeum, P. placenta* or *T. versicolor* in soil block tests.

Test Fungus	Exposure Period [a]							
	3 wk		6 wk		9 wk		12 wk	
	M C (%)	W L (%)	M C (%)	W L (%)	M C (%)	W L (%)	M C (%)	W L (%)
G. trabeum	34.4 (3.5)	4.9 (2.9)	44.5 (6.1)	17.1 (5.7)	57.9 (10.1)	30.0 (6.9)	64.6 (8.3)	36.1 (6.3)
P. placenta	31.6 (1.4)	2.5 (0.5)	37.9 (3.1)	9.6 (3.3)	46.1 (5.7)	18.7 (4.6)	64.8 (6.6)	35.9 (6.2)
T. versicolor	30.3 (3.5)	3.2 (1.1)	34.9 (2.8)	7.5 (1.8)	42.6 (3.9)	15.7 (3.6)	54.7 (9.5)	25.2 (5.9)
Controls	29.4 (1.5)	1.4 (0.5)	29.7 (1.9)	0.9 (0.7)	30.2 (2.3)	1.7 (1.1)	29.8 (5.7)	1.2 (1.1)

[a] Values represent means of seven samples per time per fungus. Values in parentheses represent one standard deviation.

Table 3. Moisture contents (MC) and weight losses (WL) of maple WPC's exposed to *G. trabeum, P. placenta,* or *T. versicolor* on agar (MEA and PDA) on soil block tests.

Fungi	Culture media	MC (%)	WL (%)
G. trabeum	soil block tests [a]	64.6 (8.3) D	36.1 (6.3) CDE
	MEA (0.5%) [b]	69.9 11.0) CD	38.3 (8) CD
	MEA (1%)	68.3 (10.1) CD	36.7 (8) CDE
	MEA (1.5%)	68.9 (7.3) CD	35.4 (5.6) DE
	PDA (0.5%) [b]	35.0 (3.6) LMNOP	6.9 (3.6) PQRS
	PDA (1%)	36.6 (2.1) KLMN	2.2 (1.6) STUVW
	PDA (1.5%)	43.3 (12.4) HIJK	12.0 (12.4) LMNOPQ
P. placenta	soil block tests	64.8 (6.6) D	35.9 (6.2) CDE
	MEA (0.5%)	67.5 (9.8) CD	37.3 (7.1) CDE
	MEA (1%)	70.8 (7.2) CD	39.8 (5.8) CD
	MEA (1.5%)	67.8 (7.5) CD	36.9 (3.9) CDE
	PDA (0.5%)	74.3 (12.7) C	41.7 (8.6) BC
	PDA (1%)	87.2 (4.4) B	47.7 (4.6) A
	PDA (1.5%)	81.2 (8.3) B	45.4 (6.3) AB
T. versicolor	soil block tests	54.7 (9.5) EF	25.2 (5.9) GH
	MEA (0.5%)	52.4 (8.7) EFG	17.2 (5.8) JKLM
	MEA (1%)	45.0 (4.2) HIJ	15.1 (2.7) KLMNO
	MEA (1.5%)	44.3 (5.0) HIJK	12.2 (3.9) LMNOP
	PDA (0.5%)	56.9 (16.1) E	20.5 (12.5) IJK
	PDA (1%)	64.8 (16.3) D	29.3 (12.5) FG
	PDA (1.5%)	95.6 (21.2) A	49.1 (11.5) A

a Values of the soil block tests represent means of 14 samples (7 samples x 2 replicas).
b MEA = malt extract agar, PDA =potato dextrose agar, n=7. Values of the MEA or PDA tests represent means of seven samples. Figures in parentheses represent one standard deviation. Values followed by the same letter(s) do not differ significantly by Duncan's multiple-range test ($\forall = 0.5$).

Table 4. Moisture contents (MC) and weight losses (WL) of the wood component in a maple WPC exposed for 3 to 12 weeks on MEA or PDA to *G. trabeum, P. placenta* or *T. versicolor,* or left non-exposed.

Test Fungus	Culture Media	Concentration (%)	Exposure Period [a]					
			3 wk		6 wk	9 wk	12 wk	
			M C (%)	W L (%)	W L (%)	W L (%)	M C (%)	W L (%)
G. trabeum	MEA[a]-	0.5	32.3 (1.6)	2.9 (1.1)	19.6 (3.8)	32.2 (4.9)	69.9 (11.0)	38.3 (8)
		1	27.0 (1.9)	4.5 (1.2)	23.3 (3.9)	25.8 (2.6)	68.3 (10.1)	36.7 (8)
		1.5	30.1 (2.0)	5.9 (1.2)	20.2 (6.2)	26.3 (4.6)	68.9 (7.3)	35.4 (5.6)
	PDA	0.5	28.1 (2.6)	2.5 (1.4)	2.4 (0.5)	2.7 (1.3)	35.0 (3.6)	6.9 (3.6)
		1	36.1 (1.5)	2.5 (0.6)	1.5 (0.5)	2.8 (0.5)	36.6 (2.1)	2.2 (1.6)
		1.5	33.9 (2.6)	2.9 (1)	1.5 (0.4)	5.5 (3.5)	43.3 (12.4)	12.0 (12.4)
P. placenta	MEA	0.5	26.1 (2.6)	3.4 (1)	13.1 (3.2)	23.0 (6.4)	67.5 (9.8)	37.3 (7.1)
		1	30.2 (2.6)	3.6 (0.6)	10.4 (2.4)	29.2 (3.5)	70.8 (7.2)	39.8 (5.8)
		1.5	28.7 (2.2)	2.6 (0.4)	12.4 (3)	19.0 (3.7)	67.8 (7.5)	36.9 (3.9)
	PDA	0.5	29.0 (2.4)	2.8 (1.3)	15.0 (5.5)	30.0 (6.4)	74.3 (12.7)	41.7 (8.6)
		1	34.8 (2.6)	2.0 (0.8)	14.3 (2.1)	2.4 (0.5)	87.2 (4.4)	47.7 (4.6)
		1.5	37.4 (0.8)	5.9 (0.4)	16.1 (4.3)	35.6 (4.1)	81.2 (8.3)	45.4 (6.3)
T. versicolor	MEA	0.5	27.0 (4.7)	0.6 (0.3)	6.5 (3.2)	12.8 (3.3)	52.4 (8.7)	17.2 (5.8)
		1	25.7 (3.3)	1.7 (0.8)	6.6 (2.7)	8.1 (2.2)	45.0 (4.2)	15.1 (2.7)
		1.5	24.7 (1.8)	2.2 (0.6)	3.6 (1.3)	14.5 (2.3)	44.3 (5.0)	12.2 (3.9)
	PDA	0.5	36.7 (2.4)	6.4 (2.3)	9.1 (3.7)	15.8 (9.5)	56.9 (16.1)	20.5 (12.5)
		1	39.8 (5.7)	7.3 (3.8)	16.0 (2.3)	32.1 (8.7)	64.8 (16.3)	29.3 (12.5)
		1.5	39.2 (2.5)	6.0 (1.2)	15.2 (2.6)	32.3 (8.9)	95.6 (21.2)	49.1 (11.5)
controls	MEA	0.5	28.0 (2.0)	0.3 (0.7)	0.8 (0.5)	1.0 (1.2)	31.8 (2.5)	1.8 (0.7)
		1	27.7 (1.9)	0.0 (0.7)	1.3 (0.8)	1.5 (0.3)	30.7 (1.2)	1.6 (0.7)
		1.5	28.0 (1.8)	1.6 (0.5)	1.0 (0.3)	2.1 (1.2)	33.3 (4.0)	0.7 (0.3)
	PDA	0.5	31.7 (1.2)	1.8 (0.3)	1.1 (0.4)	2.4 (1.5)	30.9 (2.3)	1.1 (0.5)
		1	33.2 (1.3)	1.5 (0.6)	1.5 (0.7)	0.5 (0.6)	33.7 (1.8)	1.6 (0.7)
		1.5	34.3 (2.1)	2.0 (0.6)	0.6 (0.2)	0.8 (0.3)	33.7 (2.4)	1.7 (0.9)

[a] MEA = malt extract agar, PDA = potato dextrose agar.
[b] Values represent means of seven samples. Values in parentheses represent one standard deviation.

Table 5. Effect of glucose concentration and carbon to nitrogen ratio (C:N) on moisture content (MC) and weight loss (WL) of the wood component in a maple WPC exposed to selected decay fungi on basal salts media.

Fungi	Glucose (%)	C:N ratio	Exposure Period [1]							
			3 weeks		6 weeks		9 weeks		12 weeks	
			M C (%)	W L (%)	M C (%)	W L (%)	M C (%)	W L (%)	M C (%)	W L (%)
G. trabeum	1.5	100:1	28.7 (1.0)	2.4 (1.4)	31.6 (1.0)	2.3 (0.6)	32.2 (1.9)	1.8 (0.4)	31.5 (3.1)	1.9 (1.7)
	1.5	500:1	29.3 (1.7)	0.7 (1.0)	33.6 (1.5)	3.0 (1.7)	32.3 (2.4)	0.7 (1.8)	35.7 (3.1)	0.9 (0.7)
	2.5	100:1	27.3 (2.3)	1.3 (1.2)	33.7 (1.7)	0.8 (0.8)	33.3 (0.7)	1.4 (0.9)	31.5 (3.5)	1.1 (1.3)
	2.5	500:1	29.7 (1.9)	2.9 (2.4)	33.3 (1.7)	2.3 (1.1)	32.9 (1.4)	1.5 (1.2)	34.7 (2.9)	4.1 (2.0)
P. placenta	1.5	100:1	30.0 (2.9)	1.2 (1.3)	33.0 (1.5)	2.2 (0.6)	32.4 (0.7)	2.2 (0.6)	33.3 (2.4)	1.0 (0.8)
	1.5	500:1	30.2 (1.8)	1.5 (0.6)	33.1 (1.3)	2.1 (0.8)	33.2 (1.5)	2.5 (0.7)	34.4 (2.4)	1.2 (0.7)
	2.5	100:1	29.7 (1.8)	1.3 (0.7)	33.2 (2.1)	0.6 (0.8)	32.6 (1.0)	0.8 (0.6)	31.6 (2.8)	5.3 (10.7)
	2.5	500:1	29.9 (2.5)	1.9 (1.3)	33.6 (1.3)	1.5 (1.1)	33.0 (0.9)	0.3 (0.9)	34.3 (2.7)	2.4 (1.0)
T. versicolor	1.5	100:1	31.5 (1.6)	4.7 (1.1)	40.1 (6.9)	9.4 (4.8)	58.7 (7.1)	28.1 (5.6)	46.9 (8.4)	15.1 (7.1)
	1.5	500:1	30.6 (2.2)	2.2 (0.8)	40.2 (4.9)	10.8 (4.0)	53.3 (13.2)	23.7 (9.6)	57.7 (6.0)	26.4 (4.4)
	2.5	100:1	30.9 (1.2)	3.4 (1.1)	38.3 (4.2)	6.9 (3.6)	43.6 (2.8)	13.0 (2.7)	44.3 (8.3)	13.4 (8.0)
	2.5	500:1	31.9 (3.1)	3.0 (1.9)	41.8 (2.6)	10.4 (1.9)	59.5 (11.5)	25.3 (8.3)	60.5 (20.3)	22.8 (11.7)
Controls	1.5	100:1	24.3 (4.2)	1.9 (2.4)	33.3 (2.0)	0.4 (0.8)	31.9 (1.9)	1.4 (0.7)	33.4 (1.7)	1.9 (1.0)
	1.5	500:1	31.3 (0.7)	0.0 (1.0)	32.3 (1.0)	4.6 (6.2)	32.9 (0.7)	1.4 (0.6)	30.6 (3.7)	1.6 (0.8)
	2.5	100:1	30.9 (3.7)	1.2 (0.6)	31.0 (1.8)	1.5 (1.0)	31.5 (2.5)	1.1 (1.0)	31.8 (1.5)	1.1 (0.2)
	2.5	500:1	25.5 (0.8)	1.3 (0.7)	32.6 (1.1)	1.9 (0.9)	31.4 (1.5)	1.1 (0.9)	32.8 (1.7)	0.8 (0.4)

[1] Average moisture contents and weight losses are the means of seven samples per treatment. Values in parentheses are standard deviations.

Table 6. Moisture contents (MC) and weight losses (WL) of the maple component of maple WPC's of varying thicknesses exposed on 1% MEA to *G. trabeum, P. placenta* or *T. versicolor* for 3 to 15 weeks.

Test Fungus	Wood species and thickness (mm)		Exposure Period (weeks)[a]						
			3		6	9	12	15	
			M C (%)	W L (%)	W L (%)	W L (%)	W L (%)	M C (%)	W L (%)
G. trabeum	Maple	0.5	28.8 (3.9)	9.3 (1.6)	17.0 (4.1)	21.5 (2.5)	27.1 (6.6) A	51.4 (7.1)	21.0 (5.2)
		2.5	27.9 (0.8)	2.9 (0.4)	5.9 (1.1)	5.2 (1.0)	8.4 (1.1) DC	35.1 (1.1)	8.0 (0.7)
		5	29.0 (0.9)	2.1 (0.3)	3.8 (0.4)	5.7 (0.3)	5.4 (0.4) EF	36.1 (1.2)	6.9 (0.4)
		8	30.5 (2.0)	1.9 (0.2)	3.8 (0.8)	5.2 (0.5)	6.0 (1.0) DE	36.7 (3.4)	6.4 (0.9)
P. placenta	Maple	0.5	29.8 (3.4)	3.4 (1.1)	5.8 (2.0)	11.9 (3.1)	19.3 (3.8) B	56.5 (15.1)	24.0 (14.0)
		2.5	27.2 (1.0)	1.2 (0.3)	1.8 (0.5)	3.7 (1.2)	6.0 (1.9) DE	38.9 (2.1)	12.7 (2.0)
		5	27.9 (1.1)	1.3 (0.3)	1.6 (0.3)	1.9 (0.3)	2.7 (0.8) GHIJ	34.8 (1.5)	5.1 (1.0)
		8	29.0 (1.4)	0.9 (0.2)	1.2 (0.3)	3.2 (0.7)	3.8 (0.8) EFGH	32.9 (1.9)	3.7 (1.7)
T. versicolor	Maple	0.5	30.7 (1.6)	2.8 (0.8)	5.4 (2.1)	11.1 (2.9)	12.5 (8.2) C	54.0 (10.3)	18.5 (7.2)
		2.5	26.7 (0.7)	1.2 (0.3)	1.5 (0.5)	2.4 (0.5)	2.6 (1.4) GHIJ	35.5 (2.4)	5.5 (2.2)
		5	28.7 (0.8)	1.4 (0.2)	1.5 (0.2)	2.9 (0.5)	1.6 (0.4) HIJ	34.4 (1.6)	4.5 (0.8)
		8	29.1 (0.9)	1.2 (0.1)	1.6 (0.2)	1.8 (0.3)	1.3 (0.4) HIJ	37.6 (1.5)	4.6 (0.8)
Controls	Maple	0.5	32.6 (1.9)	2.8 (1.4)	0.6 (0.7)	0.9 (0.5)	1.4 (0.9) HIJ	33.8 (2.6)	2.2 (0.9)
		2.5	28.3 (0.7)	1.3 (0.3)	1.0 (0.2)	0.9 (0.2)	0.6 (0.3) IJ	29.9 (0.9)	1.7 (0.1)
		5	29.6 (1.2)	1.3 (0.1)	0.9 (0.0)	1.1 (0.1)	0.5 (0.1) IJ	31.1 (1.1)	1.9 (0.5)
		8	29.5 (0.8)	0.9 (0.1)	0.6 (4.9)	0.9 (0.1)	0.0 (0.1) IJ	32.1 (1.6)	1.5 (0.1)

[a] MC and WL values estimated based on the wood component of the WPC. Average moisture content and weight loss are the means of 7 specimens per treatment. Values in the parenthesis are standard deviations. Weight loss values at 12 weeks followed by the same letter(s) do not differ significantly by Duncan's multiple range test at $\forall$=0.05.

Table 7. Moisture contents (MC) and weight losses (WL) of the pine component of a pine WPC of varying thicknesses exposed on 1% MEA to *G. trabeum, P. placenta* or *T. versicolor* for 3 to 15 weeks.

Test Fungus	Wood species and thickness (mm)		Exposure Period (weeks)[a]						
			3		6	9	12	15	
			M C (%)	W L (%)	W L (%)	W L (%)	W L (%)	M C (%)	W L (%)
G. trabeum	Pine	0.5	15.2 (1.4)	1.3 (0.8)	3.4 (0.6)	7.4 (0.9)	3.8 (1.1)ABC	22.2 (0.7)	5.9 (0.7)
		2.5	16.5 (0.8)	1.6 (0.2)	2.1 (0.4)	3.3 (0.6)	2.2 (0.4) DEF	19.7 (1.1)	3.5 (0.6)
		5	16.7 (1.1)	1.4 (0.4)	2.5 (0.4)	2.7 (0.6)	1.8 (0.6) DEF	19.5 (1.8)	2.9 (0.7)
		8	17.1 (1.5)	1.0 (0.2)	2.0 (0.1)	2.6 (0.3)	1.7 (0.5) DEF	20.4 (1.6)	3.0 (0.4)
P. placenta	Pine	0.5	16.8 (1.1)	1.4 (1.2)	2.5 (1.1)	4.4 (1.0)	5.1 (2.3) ABC	24.3 (2.2)	8.8 (3.7)
		2.5	16.7 (2.3)	1.2 (0.3)	0.8 (0.2)	2.7 (0.2)	1.8 (0.3) DEF	20.4 (1.0)	4.8 (0.5)
		5	15.5 (1.4)	0.5 (0.4)	1.0 (0.2)	3.1 (0.7)	3.0 (0.4) BCDE	19.0 (1.6)	2.4 (0.7)
		8	15.4 (1.6)	0.4 (0.5)	1.1 (0.2)	2.5 (0.4)	1.7 (0.4) DEF	20.6 (1.7)	2.9 (0.5)
T. versicolor	Pine	0.5	17.9 (1.5)	2.3 (1.5)	1.4 (0.7)	2.1 (1.2)	1.8 (1.0) DEF	21.2 (4.7)	2.3 (0.9)
		2.5	17.1 (0.9)	0.8 (0.2)	0.6 (0.2)	1.1 (0.3)	0.3 (0.2) EF	19.2 (0.8)	1.4 (0.3)
		5	17.0 (3.0)	0.7 (0.2)	1.2 (0.2)	1.2 (0.3)	0.5 (0.3) EF	18.5 (0.7)	1.1 (0.1)
		8	17.1 (1.4)	0.5 (0.1)	0.8 (0.3)	0.9 (0.1)	0.2 (0.1) EF	20.8 (1.3)	1.1 (0.1)
controls	Pine	0.5	18.3 (0.9)	2.2 (0.6)	0.9 (0.9)	3.8 (0.7)	0.2 (0.9) EF	18.3 (2.5)	1.3 (0.7)
		2.5	17.8 (0.7)	0.9 (0.2)	0.5 (0.1)	1.1 (0.1)	-0.2 (0.1) F	16.4 (3.2)	-0.3 (3.2)
		5	17.7 (1.7)	0.6 (0.2)	0.8 (0.1)	0.9 (0.2)	0.2 (0.1) EF	18.0 (1.0)	0.8 (0.2)
		8	18.1 (3.1)	0.4 (0.2)	0.6 (0.1)	0.7 (0.0)	-0.3 (0.2) F	19.0 (1.6)	0.7 (0.1)

[a] MC and WL values estimated based on the wood component of the WPC. Average moisture content and weight loss are the means of 7 specimens per treatment. Values in parentheses are standard deviations. Weight loss values at 12 weeks followed by the same letter(s) do not differ significantly by Duncan's multiple range test at $\forall$=0.05.

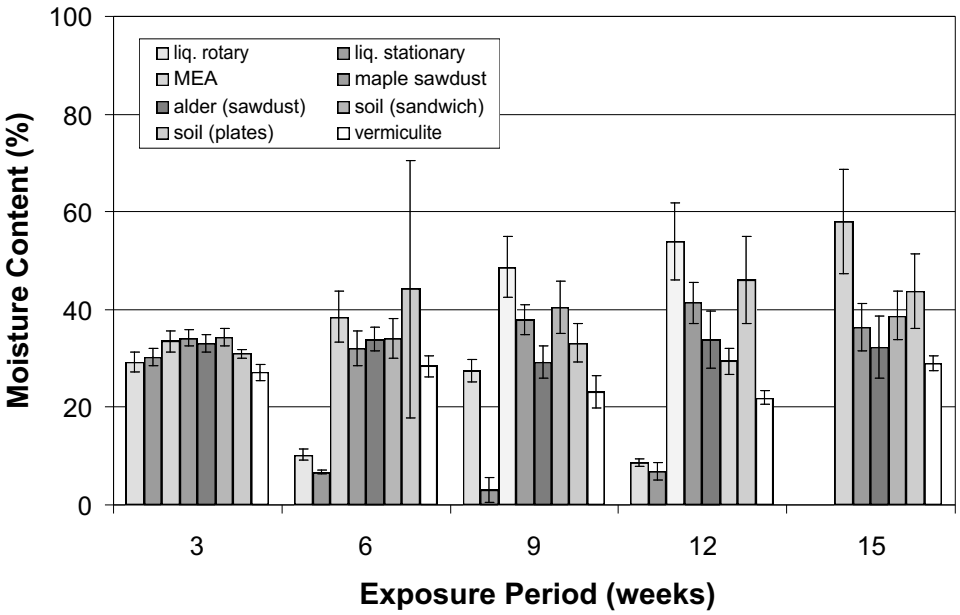

Figure 1. Moisture contents of the wood component of a maple WPC following exposure to *T. versicolor* for 4 to 15 weeks using various decay systems. Values represent ten replicates per treatment. Error bars represent one standard deviation.

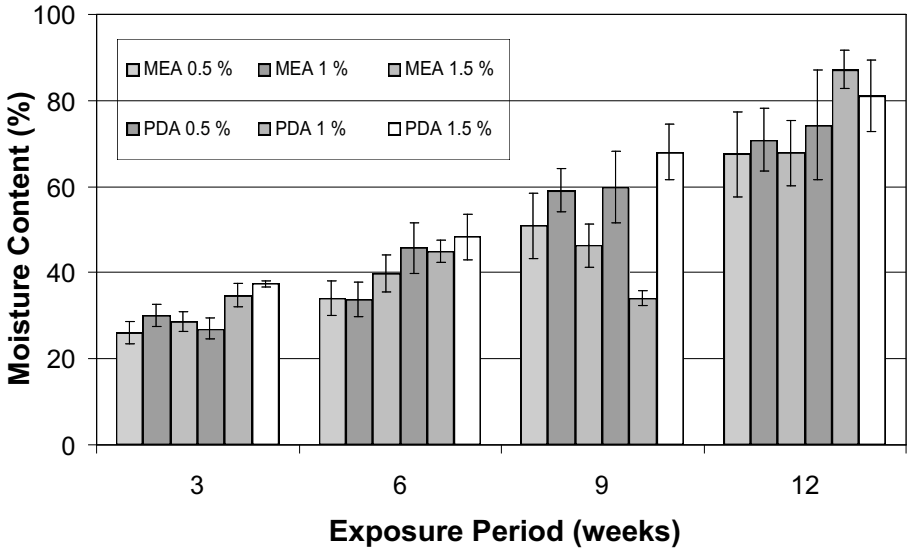

Figure 2. Moisture contents of the wood component in a maple WPC exposed for 3 to 12 weeks to *P. placenta* in petri dishes containing 0.5, 1.0, or 1.5% malt extract agar (MEA) or potato dextrose agar (PDA). Errors bars represent one standard deviation.

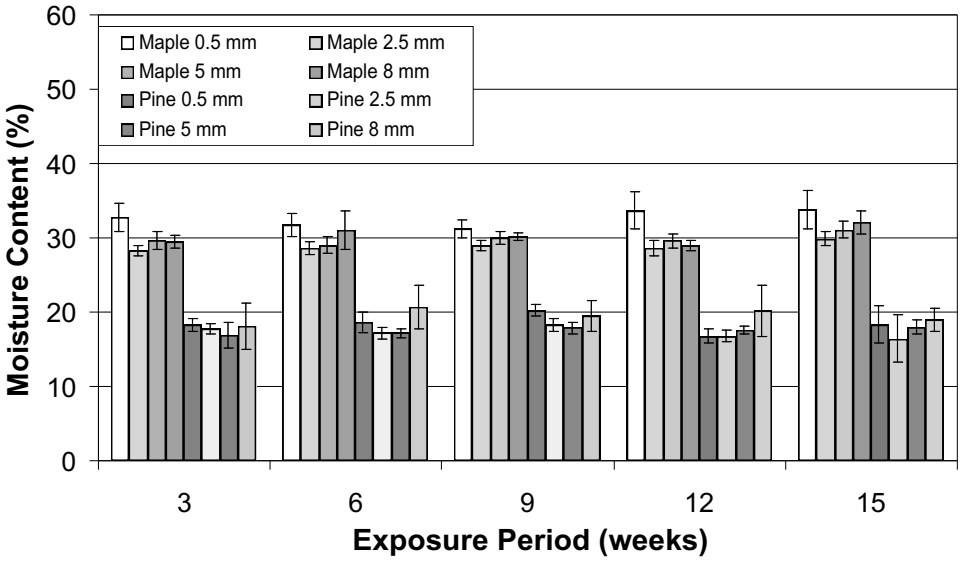

Figure 3. Influence of wood species and composite thickness on moisture contents of the wood component of non-fungal exposed maple WPC controls exposed for 3 to 12 weeks in malt extract agar. Error bars represent one standard deviation.

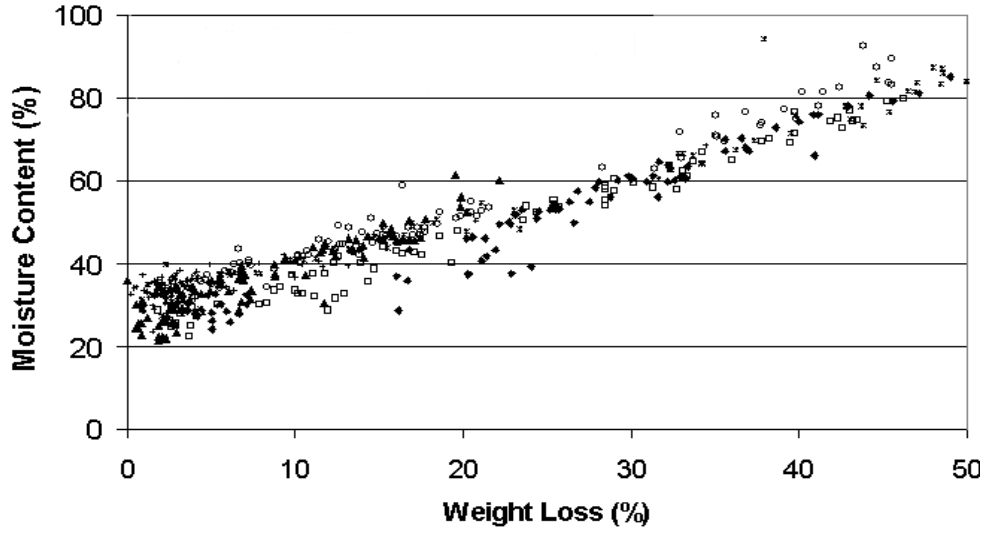

Figure 4. Relationship between moisture content and weight loss in maple WPC specimens exposed to selected decay fungi in agar tests for 3 to 12 weeks on various levels of MEA or PDA.