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Termite response to Agricultural fiber composites: Bagasse

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Termite Response to Agricultural Fiber Composites: Bagasse

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Abstract

Bagasse, or sugarcane rind, is a fibrous by-product of sugar extraction from sugarcane, *Saccharum officinarum* L. Bagasse fiber performs similarly to hardwood fiber in composite board products. In laboratory studies, Formosan subterranean termites survived as well on a diet of bagasse as on Douglas-fir wood. Field tests with a compressed bagasse panel (produced by heat extrusion) indicated that termites readily penetrated the acrylic/vinyl latex coating on the panel, and tunneled throughout the interior bagasse fibers. Treatment of the fibers with disodium octaborate tetrahydrate did not prevent termite penetration of the panel exterior. Subsequent moisture sorption by the fibers led to rapid swelling and deformation of the panels. A dimensionally stable, high density bagasse particleboard was also evaluated in laboratory tests. No swelling was noted, although the particleboard was readily penetrated and consumed by Formosan subterranean termites, and mold growth was also noted on the test wafers. In recent years, high-profile bagasse board production facilities were opened in both Louisiana and Hawaii, only to close shortly thereafter. Bagasse may have more market potential in a value-added, preservative treated product than as a low-end commodity competing with comparable wood products.

Key Words: *Coptotermes formosanus*, Formosan subterranean termite, *Saccharum officinarum*, sugarcane

Introduction

Efficient use of agricultural residues is a desirable goal from both environmental and economic standpoints. In a changing economy, it is even possible that the by-products of today may become the primary products of tomorrow. For example, sugarcane (*Saccharum officinarum* L.) cultivation has declined precipitously in Hawaii over the past two decades, as rapidly rising labor costs and land values undermined the economic viability of plantation agriculture with a commodity crop. Under these conditions, the additional revenue stream offered by commercial use of bagasse, the fibrous by-product of sugar extraction, may be essential for the industry to survive.

Use of agricultural fibers in building products represents a high-value application, in comparison to the common use as fuel or mulch. Bagasse fiber performs similarly to hardwood fiber in composite board products, and there has been considerable interest in developing such products in the two major sugar-producing regions of the United States: Hawaii and Louisiana. This interest has run the gamut from cheaply produced products for local construction use (Grace 1996) to more refined and dimensionally stable fiberboards (Rowell and Keany 1991) and particleboards (Wu 2003, Youngquist et al. 1996).

Despite the claims of some proponents of increased use of agricultural fibers, susceptibility to termites and decay fungi is as important an issue with agricultural fiber composites as it is with wood products. In this paper, I summarize results of an earlier study (Grace 1996) on the susceptibility of bagasse fibers and of panels made from compressed bagasse (by heat extrusion) to attack by the Formosan subterranean termite, and describe new results with a bagasse particleboard manufactured in Hawaii.

The compressed bagasse panel (Envirocor™, Mansion Industries Inc.) can be made from a variety of agricultural fibers (rye, wheat, barley, rice straw, or bagasse) by heat extrusion, and is covered with Kraft paper bonded with a film of urea-formaldehyde resin, and finished with an acrylic/vinyl coating. It was intended by the manufacturer as a locally-produced building material for affordable housing, and has 40% of the density of solid wood, but equal thermal performance (DiChristina 1991; Mansion Industries, undated). Marketing literature referred to the paneling as “immune to termite infestation.”

The bagasse board was an experimental high-density particle board manufactured by Hawaiian Commercial and Sugar Company (HC&S) on behalf of its sister unit within Alexander & Baldwin Inc., Hawaiian DuraGreen. Hawaiian DuraGreen both began and ceased operations in 2001, as the manufacturer of a medium-density fiberboard using bagasse from the Maui-based sugar-processing operations of HC&S (Natarajan 2001, Alexander & Baldwin 2002).

Materials and Methods

<u>Acceptability of bagasse as a food source for termites</u>

Bagasse samples from Maui, Hawaii, were provided by Maui Commercial and Sugar Company; and samples from the Philippines were provided by Mansion Industries, Inc. (City of Industry, California). Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) heartwood wafers (2.5 x 2.5 x 0.6 cm) were included as a positive (feeding) control. Formosan subterranean termites, *Coptotermes formosanus* Shiraki, were collected from a field colony on the Manoa campus of the University of Hawaii immediately before use in the laboratory, using a trapping technique (Tamashiro et al. 1973).

Test containers were 80 mm diameter by 100 mm high screw-top plastic jars, each containing 150 g silica sand moistened with 30 ml distilled water. 400 termites (360 workers and 40 soldiers, to approximate natural caste proportions) were added to each jar, and provided with either 8 g of bagasse from Maui or the Philippines, a single Douglas-fir wafer (ca. 2.5 g), or no food (starvation control). Five replicates of each treatment were kept in an unlighted cabinet at 28 °C for four weeks (28 days). At the end of this period, termite mortality was recorded.

Termite resistance of compressed bagasse panels

Miniature panels (blocks) ca. 100 mm on each side manufactured by the Envirocor process were prepared by Mansion Industries, Inc. (California), by heat extrusion (205 °C) of the compressed fibers, with no additives. One set of panels was coated on all sides with a 2-mm thick acrylic/vinyl coating; a second set was wrapped only with Kraft paper (bonded with a film of UF resin adhesive) on 4 sites, with the ends left open to expose the fibers directly to foraging termites; and a third set was dipped before coating in a 1% aqueous solution of disodium octaborate tetrahydrate (Tim-Bor®, US Borax Inc.).

Three panels from each of the three treatments (untreated + uncoated, untreated + coated, treated + coated) were placed, individually, in contact with foraging Formosan subterranean termites at a field site on the Manoa campus of the University of Hawaii. Each panel was placed on a hollow concrete tile (51 mm high) on the soil surface, covered by a wooden box, and then covered by a 5-gallon metal can. Termites had been actively foraging on wood within each of these containers prior to installation of the test materials. The two sets of untreated test samples (three replicates per set) were left in the field for 4 weeks, with weekly observations; while the three borate-treated samples were examined after 7 weeks in the field.

Termite resistance of bagasse particleboard

Test wafers (2.5 x 2.5 x 1.2 cm) were cut from bagasse particleboard prepared by Hawaiian Commercial & Sugar Company. This is a rather dense board with relatively small bagasse particles, with a smooth face. As described in the American Wood-Preservers' Association Standard Method E1-97 (AWPA 2003), wafers were oven dried (90° C, 24 hours) to obtain dry weights prior to termite exposure. Wafers of similar dimensions (2.5 x 2.5 x 0.6 cm) were cut from Douglas-fir heartwood. The test conducted was a no-choice (or single-choice) test in which termites were presented either with a wafer of bagasse board or a wafer of susceptible Douglas-fir on the surface of 150 g of damp silica sand (moistened with 30 ml distilled water) inside a screw-top jar (8 cm diameter, 10 cm high).

Formosan subterranean termites were collected from an active field colony at the Poamoho Experiment Station (Oahu, Hawaii) immediately before the laboratory test using a trapping technique (Tamashiro et al. 1973). 400 termites (360 workers and 40 soldiers, to approximate natural caste proportions in field colonies) were added to each test jar. Both the no-choice and two-choice tests were replicated 6 times. We also included 3 additional wafers of each material as "environmental controls" - exposed to the same test conditions as the other wafers, but without addition of any termites to the jar - in order to recognize any weight change in the wafers due to absorbing moisture, possible decay, or any other factors unrelated to termite attack.

After adding termites, the jars were placed in an unlighted controlled-temperature cabinet at 28° C for 4 weeks (28 days). Each jar was inspected weekly for evidence of termite activity in the soil and on the test materials. At the conclusion of the 4-week test period, percentage termite mortality was recorded, the wafers were rated visually according to a 0-10 scale (where 10 is sound, 9 is light attack, 7 is moderate attack and penetration, 4 is heavy attack, and 0 is total failure of the wood sample), and the oven-dry weight change was recorded for each wafer.

Results and Discussion

Bagasse fiber proved to be as adequate a food source for Formosan subterranean termites as Douglas-fir wood, with equivalent numbers of termites surviving on a diet of either material (TABLE 1).

TABLE 1. Survival of Formosan subterranean termites on bagasse or Douglas-fir wood in a 4-week, no-choice laboratory test.

Food	Mean % Termite Survival (SD)[a]	
Bagasse - Philippines	77.50 (3.17)	A
Bagasse - Maui (Hawaii)	71.45 (8.83)	A
Douglas-fir wood	77.30 (7.69)	A
No Food (Starved)	38.35 (7.35)	B

[a] Standard Deviation in parentheses. Means followed by the same letter do not differ significantly at the 0.05 level (ANOVA, Ryan-Einot-Gabriel-Welsch multiple F test).

Both the coated and uncoated compressed bagasse panels were penetrated by termites. The coated panels all evidenced multiple penetrations of the exterior coating by termites within one week after installation in the field. Borate treatment of the interior fibers may have limited actual termite feeding on the bagasse fibers (not evaluated in this study), but did not prevent penetration of the exterior coating, nor tunneling through the interior by termites. Termite imported soil and constructed carton (a mixture of soil, masticated fibers, and salivary and fecal secretions) within the panels. By the end of the field exposure, swelling and separation of the fibers due to moisture sorption caused the panels to deform and increase in size from 0.25 to almost 2 times their initial volume (FIGURE 1).

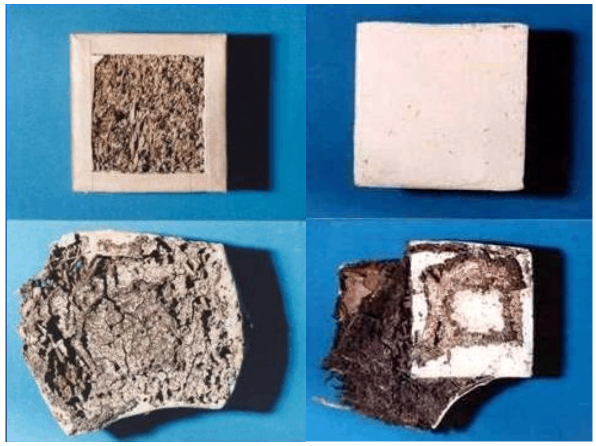

FIGURE 1. Compressed bagasse panels before (top) and after (bottom) exposure to Formosan subterranean termites in the field for four weeks. Note swelling of fibers due to moisture sorption.

The bagasse particleboard was not subject to the swelling and dimensional changes noted with the compressed bagasse panels. The particleboard wafers suffered significant damage from termite feeding (mean visual rating of 6), but less damage than the Douglas-fir wafers (mean visual rating of 0.7) (TABLE 2, FIGURE 2). When the mass loss of the wafers was adjusted by the mass change observed in the control wafers that were not exposed to termites, termites consumed approximately 33% less particleboard than Douglas-fir wood. The control particleboard wafers suffered ca. 5% mass loss in the absence of termites, either due to residual moisture retained in the wafers when they were weighed prior to the test, or (more likely) due to slight decay attributable to fungus growth visible on the surface of the wafers at the conclusion of the test.

TABLE 2. Results of a 4-week, no-choice laboratory test exposing bagasse particleboard or Douglas-fir wafers to Formosan subterranean termites.

Treatment	Mean Visual Rating (Range)	Mean mg Mass Loss (SD)[a]	Mean % Termite Mortality (SD)
Bagasse Particleboard	6.0 (4-7)	676.03 (75.59)	32.63 (4.98)
Douglas-fir wood	0.7 (0-4)	987.85 (70.97)	26.96 (9.53)

[a] Mass losses adjusted by mean mass loss of control wafers not exposed to termites: Bagasse particleboard - 291.53 mg, Douglas-fir wafers - 18.93 mg.

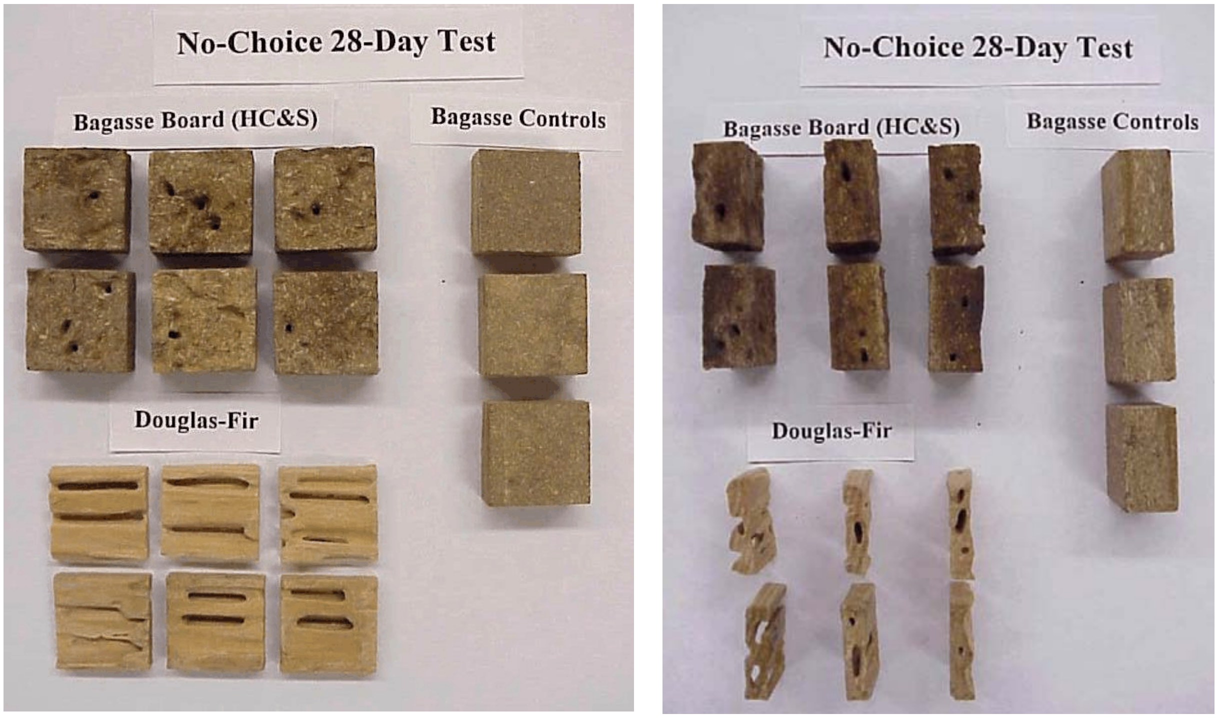

FIGURE 2. Face view (Left) and side view (Right) of bagasse particleboard and Douglas-fir wafers after 4-weeks exposure to Formosan subterranean termites.

As in the test with bagasse fiber alone, the bagasse particleboard was an adequate food source for termites, evidenced by the relatively low termite mortality (TABLE 1).

One can conclude from these evaluations that bagasse fiber and bagasse composite materials are susceptible to termite attack, as is sugarcane (Lai et al. 1983). Incorporation of a preservative into the bagasse particleboard to deter both termites and decay fungi, and use of either a repellent insecticide or impregnable coating on the compressed bagasse panels would be recommended to prevent termite penetration of these products. Swelling of bagasse fibers from moisture sorption is also a significant issue in non-arid environments, but the dimensional stability of the particleboard product in this study indicates that this can be overcome, as does prior work with acetylated fibers (Rowell and Keany 1991).

In the past several years, bagasse board production facilities opened with much fanfare in both Louisiana and Hawaii, the major sugarcane growing regions of the United States. Both facilities focused on manufacture of low-end composite products from the residue of sugar production, and both ceased operations within one year due to their inability to compete successfully with low-end wood building products (Hundley 2002, Natarajan 2001, Alexander & Baldwin 2002). However, bagasse represents an under-utilized source of cellulose fiber with no significant agricultural cost (since it is an inevitable by-product of sugar production). In contrast to such low-end products, well-engineered and value-added bagasse composites might prove quite attractive to consumers.

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