IRG/WP 99-10312

THE INTERNATIONAL RESEARCH GROUP ON WOOD PRESERVATION

Section 1 Biology

Preliminary Indications of the Natural Durability of Spruce Bark Board

P.I. Morris[1] J. K. Grace[2] G.E. Troughton[1]

[1]: Forintek Canada Corp.
2665 East Mall, Vancouver, BC
Canada, V6T 1W5

[2]. University of Hawaii
3050 Maile Way, Honolulu
USA, HI 96822

Paper prepared for the 30th Annual Meeting
Rosenheim Germany
6th – 11th June 1999

IRG Secretariat
SE-100 44 Stockholm
Sweden

Preliminary Indications of the Natural Durability of Spruce Bark Board

by

P.I. Morris[1] J. K. Grace[2] G.E. Troughton[1]

[1]: Forintek Canada Corp.
2665 East Mall, Vancouver, BC
Canada, V6T 1W5

[2]. University of Hawaii
3050 Maile Way, Honolulu
USA, HI 96822

ABSTRACT

A board material made from pressed spruce bark, with no added adhesive, has been developed by Forintek's composites group and tested for durability by Forintek's treated-wood group and the University of Hawaii. This material was also manufactured with veneers in a one-step process. Since one role of bark on the tree is protection against pests and diseases, bark board was expected to have some natural durability. Samples from the first boards made, were therefore subjected to a two-hour boil test, a soil-block test, a soil-bed test and two-choice and no-choice termite tests.

Preliminary findings suggest that spruce bark board is dimensionally stable and has considerable natural durability against brown rot, white rot, soft rot, and the Formosan subterranean termite. This durability can be partially transferred into veneer in a one-step pressing process and is virtually unaffected by leaching. More work will be required to fully define the natural durability of bark board, with and without veneer.

KEYWORDS:

Bark, board, durability, brown rot, white rot, soft rot, Formosan subterranean termite.

1 INTRODUCTION

At present, approximately 12 million bone-dry tonnes (BDMt) of bark residues are produced annually as a by-product of the Canadian forest products industry. Environmental agencies are invoking stricter regulations with regard to disposal of bark in a landfill. At the same time, and most notably in British Columbia, these agencies are legislating the phase-out of beehive burners, which have been used to dispose of large quantities of bark via incineration. Because of stricter environmental regulations it is become highly important to find alternative uses for bark waste in the form of higher-valued products. A good opportunity to utilize bark residues for a higher-valued product is bark board. Bark board is unique in that it can be made without using expensive synthetic adhesives since it contains natural phenolic adhesives in the bark itself.

Since one role of bark on the tree is protection against pests and diseases, bark board was expected to have some natural durability. Furthermore, bark (Delate and Grace 1995) and bark extractives (Grace 1997) of various tree species have been found to affect termite feeding and survival. Samples from the first boards made were therefore subjected to a two-hour boil test, a soil-block test, a soil-bed test and no-choice (single choice) and two-choice termite tests.

2 MATERIALS AND METHODS

2.1 Preparation of Spruce Bark Board Samples

Approximately 20kg of western white spruce bark (incorporating up to 15% wood particles) was dried in a forced-draft oven at 70°C for 72 hours and ground in a Wiley mill to pass a 5-mesh screen. The average moisture content of the resulting ground bark was 2% on an oven-dry basis.

A bark mat was made with 610 grams of ground spruce bark formed into dimensions 300 x 300 x 25 mm. The bark mat was laid between two TEFLON™ sheets to prevent the bark sticking to the metal platens. The pre-form assembly (Troughton *et al.*, 1998) was then placed between interwoven stainless steel wire mesh screens and placed in a hydraulic platen press with electric platens heated at 260°C. The mat was then compressed to 7.5mm stops with an initial pressure of 3450 kPa for one minute followed by 19 minutes pressing at 2070 kPa. The final thickness was 7.5 mm.

2.2 Preparation of One-step Veneer Overlaid Bark Board Samples

The same procedure as above was used to prepare one-step veneer overlaid bark boards except 475 grams of ground spruce bark was placed between either 0.75 mm thick lodgepole pine or 0.75mm-inch thick birch veneers and pressed in one step. The resulting thickness of the bark board core was 6.5 mm and the total thickness was 7.5 mm. The phenolic compound from the bark migrated into the veneer during pressing and bonded the veneer to the spruce bark board.

2.3 Preparation of Two-step Veneer Overlaid Bark Board Samples

A 7.5 mm bark board prepared as above was placed between 0.75 mm birch veneers. The birch veneers were coated with emulsion polymer isocyanate glue at a level of 0.16 kg/m^2 single glueline. This assembly was pressed at 1380 kPa for 60 minutes at a press temperature of 100°C to a final thickness of 9.0 mm.

2.4 Durability Tests

2.4.1 Two-hour Boil Test Method

Ten specimens (50 x 200 mm) each were cut from the spruce bark boards, one-step birch veneer overlaid bark boards and one-step lodgepole pine veneer overlaid bark boards. The specimens were measured in the mid-section on the two ends and two lengths before the 2-hour boil treatment. They were then submerged in boiling water for two hours after which they were removed and cooled. The edge thickness was then re-measured in the same positions. The average % edge thickness swelling was then calculated.

2.4.2 Soil-block Test Method

Bark board panels were milled to provide test blocks of dimensions 19 x 19 mm x panel depth. Limited amounts of material were available at the time this test was initiated, thus only spruce bark board and one-step birch-veneer bark board were tested. For the spruce bark board, twelve samples were prepared for each of the three fungi and six were leached according to the AWPA E10-91 procedure. Only six replicates were available for each fungus for the one-step birch-veneered bark board and all of these were leached. Ponderosa pine sapwood blocks were included in the test to check the virulence of the isolates. Blocks were conditioned overnight at 40EC in a forced-draught oven prior to weighing. Test blocks were arranged on cardboard trays, wrapped in polyethylene bags and sterilized with 25 Kilograys of ionizing irradiation before installation in soil jars with established fungal colonies.

The test method followed was generally as described in the AWPA E10-91 Standard for laboratory soil block testing (AWPA, 1998b). Cylindrical glass jars (500 ml) were half-filled with soil adjusted to 50% moisture content. The soil was topped with two 3 x 29 x 35 mm ponderosa pine sapwood feeder strips, the jar was closed and the assembly sterilized by autoclaving at 103.4 kPa for one hour. After cooling on a clean air bench, each jar was inoculated with one of the following wood-destroying fungi grown on 1.5% malt, 2.0% agar (Difco):

Gloeophyllum trabeum Pers. *ex* Fr.	Ftk 47D
Postia placenta (Fr.) M. Lars. *et* Lomb.	Ftk 120F
Coriolus versicolor (L. ex Fr.) Quél..	Ftk 105C

The test fungi used, are common decay fungi and the isolates used in the test are the strains specified in the AWPA E10-91 standard test. *G. trabeum* is a classical brown rot fungus which preferentially grows on softwoods. *Postia placenta* is a brown-rot fungus, but the wood it decays has some of the visual characteristics of white rot. *C. versicolor* is a white rot fungus which preferentially grows on hardwoods.

Following inoculation, jars were closed with a sterile lid containing a vent hole sealed with a membrane filter to exclude contaminants. Infected jars were incubated for three weeks at 25EC and 80% relative humidity before aseptically placing the irradiated blocks, two per jar, on top of the feeder strips.

Jars were then incubated for a further 12 weeks for the brown rot and 24 weeks for the white rot. At the end of the incubation period, blocks were removed from jars, cleaned of any adhering mycelium and weighed. Blocks were then conditioned at 40EC in a forced-draught oven and re-weighed. Block moisture contents and weight losses were then computed.

2.4.3 *Soil-bed test method*

Stakes were cut to a size of 2.5 cm wide by 25 cm long by the thickness of the board. Five samples were prepared for each of: spruce bark board, one-step pine-veneered spruce bark board, one-step birch-veneered spruce bark board and two-step birch-veneered spruce bark board. As reference material three-ply plywood was made using the same birch veneer. Five samples of this birch plywood were pressure treated with chromated copper arsenate to each of 4.0 and 6.4 kg/m^3. The intent was to compare the durability conferred on the birch veneer by bark extractives pressed into the veneer by the one-step process with that provided by CCA.

The test method is essentially as outline in AWPA E14-94. The Forintek soil bed facility is a walk-in insulated room enclosing four stainless steel troughs, 4.8 m long by 0.8 m wide, each filled with a loam-based horticultural soil modified by the addition of about 10 percent of washed river sand, overlaying a 10 cm layer of pea-sized gravel. The soil and gravel are separated by a fine plastic mesh to prevent soil from washing through the gravel. The air temperature and relative humidity are controlled by a microprocessor. Four ceiling fans provide air circulation and uniform temperature and humidity.

For this experiment, the facility was operated at a temperature of 26°C, relative humidity of 80%, and 30% soil moisture content, which is the water-holding capacity of the soil. Soil moisture was maintained by overhead mist spraying at intervals based on gravimetric monitoring of soil moisture content. Under these conditions the soil-bed heavily favours soft rot and bacterial decay. Wood-rotting basidiomycetes are rarely found in this facility.

The stakes were installed in March 1996 in a random array, to a depth of 125 mm and with 75 mm between all faces. At three-month intervals each stake was removed from the bed, brushed free of adhering soil with a soft-bristled brush, and examined for softening or discoloration due to decay, then reinstalled in the same position. Each specimen was evaluated for decay using the AWPA rating scale of 10 to 0 AWPA Standard E14-94 (AWPA 1998c). The average rating was multiplied by ten to give a log score on a scale of 100 to 0.

2.4.4 *No-choice (or Single-choice) Termite Test Method*

The test method is essentially as outlined in AWPA E1-97 (AWPA, 1998a). Test wafers were prepared as described above and consisted of (1) non-veneered spruce bark board, (2) leached non-veneered spruce bark board, (3) pine-veneered spruce bark board, (4) birch-veneered spruce bark board, (5) leached birch-veneered spruce bark board, and (6) spruce heartwood wafers as a susceptible control. Test wafers were oven-dried (90EC for 24 hours) to obtain dry mass prior to termite exposure.

Formosan subterranean termites, *Coptotermes formosanus* Shiraki, were collected from an active field colony in Kaneohe, Oahu, Hawaii, immediately before the laboratory test using a trapping technique (Tamashiro *et al.*, 1973). This method uses wooden boxes placed on the soil surface and covered by a plastic bucket to aggregate foraging termites. The infested wood was returned to our laboratory, and termites carefully separated by hand from the wood debris.

Each test wafer was placed on the surface of 150 g of damp silica sand (moistened with 30 ml distilled water) inside an individual screw-top jar (8 cm diameter, 10 cm high). Each test material was replicated six times. Four hundred termites (360 workers and 40 soldiers, to approximate natural caste proportions found in field colonies) were then added to each test jar, and the jars were placed in an unlighted controlled-temperature cabinet at 28E 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, and the wafers were rated visually according to the AWPA 10-0 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). Ovendry mass - was also recorded for each wafer, in order to determine mass loss due to termite feeding.

2.4.5 Two-choice Termite Test Method

As with the no-choice test, the two-choice test method is essentially as outlined in AWPA E1-97 (AWPA 1998a). Preparation of test wafers, preparation of the test jars with damp sand, termite collection, and addition of termites to the jars followed the same procedures as in the no-choice test. However, this test is intended to assess termite response to the test material when an alternative susceptible wood is also available. Thus, a wafer of either (1) non-veneered spruce bark board, (2) pine-veneered spruce bark board, or (3) birch-veneered spruce bark board was paired with a wafer of susceptible spruce heartwood on opposite sides of each jar, and 400 termites placed between the two wafers in each jar. At the conclusion of the 4-week (28 day) termite exposure, termite mortality was recorded, and termite attack on the paired wafers was evaluated by visual inspection according to the AWPA 0-10 scale and by ovendry mass loss.

3 RESULTS AND DISCUSSION

3.1 Two-hour boil test

The average % edge thickness swelling for the spruce bark board, one-step birch veneer overlaid bark board and one-step lodgepole pine veneer overlaid bark board were 7.3, 6.7 and 7.4% respectively. These would all be regarded as low % edge thickness swelling thereby showing excellent dimensional stability properties. Panel products such as particleboard disintegrate after a 2-hour boil treatment while oriented strandboard (OSB) exhibits an average % edge thickness swelling over 50%.

3.2 Soil-block Test

Spruce bark board was highly resistant to decay by all three fungi. *G. trabeum* failed to cause any weight loss while *P. placenta* and *C. versicolor* achieved weight losses of 3% to 4% (Table 1). A weight loss of up to 3% is normally considered to demonstrate protection against decay, since up to 3% non-structural carbohydrates may be present in wood. Bark, may however, differ in this respect. There was no increase in weight loss with leaching, indicating that the extractives providing durability are not very water soluble. Much of the durability may be ascribed to the hydrophobic nature of bark because the moisture contents of the bark board were too low for decay. Interestingly, the moisture contents were lower for the leached material than for the unleached material suggesting that some hygroscopic components may have been removed by leaching.

Table 1: Percent Weight Loss and Percent Moisture Content of Bark Board Exposed to Decay Fungi in a Soil Block Test

Board Type	Fungus	Non-Leached				Leached			
		% Weight Loss [a]		% Moisture Content [b]		% Weight Loss [a]		% Moisture Content [b]	
Bark board	*G. trabeum*	-0.2	(1.0)	22.4	(1.0)	1.0	(1.4)	15.4	(0.5)
	P. placenta	2.8	(2.8)	21.5	(1.5)	3.6	(2.6)	15.2	(2.3)
	C. versicolor	4.4	(3.5)	20.7	(2.0)	3.8	(2.6)	17.6	(2.4)
Birch-Veneer Bark board	*G. trabeum*	ND		ND		0.1	(0.2)	11.9	(0.2)
	P. placenta	ND		ND		0.2	(0.4)	12.2	(0.3)
	C. versicolor	ND		ND		0.6	(0.5)	15.3	(0.9)
Ponderosa Pine	*G. trabeum*	63.4	(5.9)	46.6	(5.2)	56.3	(4.9)	53.7	(4.0)
	P. placenta	60.6	(1.9)	52.3	(2.2)	52.7	(2.4)	47.8	(2.2)
	C. versicolor	40.2	(5.9)	41.8	(2.4)	40.0	(3.8)	41.3	(1.7)

a. Weight losses are six-sample means corrected for weight changes due to non-decay factors. Standard deviations are in parentheses.
b Moisture contents are six-sample means with standard deviations in parentheses.
ND = Not done

The extractives which migrated into the birch veneer during the pressing process must also be relatively insoluble because the birch veneer was protected against decay by all three fungi. Weight losses of ponderosa pine blocks were typical for the fungi in question indicating that the test of bark board was valid.

3.3 Soil-bed Test

Spruce bark board with no veneer was starting to show signs of failure after three years in the soil bed with a mean rating of 78.0. One of the five stakes was rated zero, one was rated 90 and the other three were still at 100 (Figure 1). One-step pine-veneered bark board was in excellent condition with a mean rating of 90 (Figure 1). All five stakes were rated 90. One-step birch-veneered bark board remained in good condition for 2.25 years, but several stakes failed after 2.5 years and only one remained in test after 3.0 years (Figure 1). Two-step birch-veneered plywood failed after 0.5 year, due to soft-rot in the birch veneer and mechanical failure of the relatively thin bark board layer.

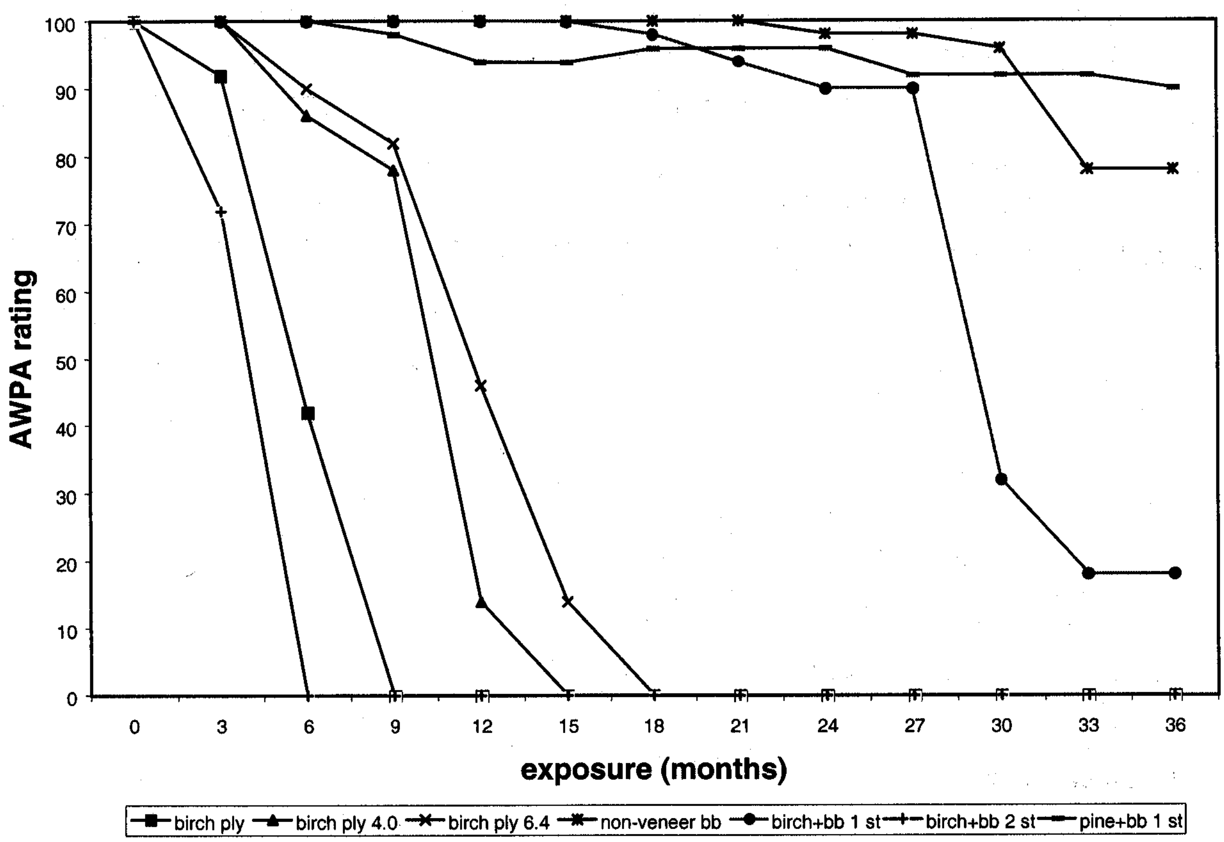

Figure 1: Bark Board in a Soil Bed Test

Of the reference materials, the untreated birch plywood failed in 0.75 year, the plywood treated to 4.0 kg/m^3 CCA failed in 1.25 years and the plywood treated to 6.4 kg/m^3 CCA failed in 1.5 years (Figure 1). The protection provided by the extractives pressed into the veneer during the one-step veneer process was better than 6.4 kg/m^3 CCA. CCA is known to be less effective in hardwoods than in softwoods, but that does not detract from the comparative efficacy of the bark extractives.

3.4 No-choice Termite Test

There was some variation in termite attack from sample to sample within each bark board treatment, particularly among the non-veneered bark board samples, suggesting that bark board is not entirely an homogeneous composite. However, based on both the visual ratings and mass losses due to termite feeding, the non-veneered spruce bark board was clearly the most resistant to termite attack, followed by the pine-veneered bark board, and then by the birch-veneered bark board (Table 2). Leaching appeared to have virtually no effect upon termite resistance of the bark board.

Table 2: Percent Weight Loss of Bark Board and Percent Mortality of Formosan Subterranean Termites in a No-choice Test

Board Type	Non-Leached						Leached					
	Mean AWPA Rating [a]		Mean % Weight Loss [a]		Mean % Mortality		Mean AWPA Rating [a]		Mean % Weight Loss [a]		Mean % Mortality	
Bark board	8.8	(2.4)	7.8	(6.7)	36.8	(31.5)	9.0	(2.5)	7.6	(5.6)	26.1	(4.2)
Birch-veneer bark board	7.7	(1.0)	18.7	(1.9)	13.4	(1.5)	7.2	(1.8)	17.6	(2.6)	14.2	(1.6)
Pine-veneer bark board	8.3	(1.0)	14.8	(0.3)	21.0	(2.7)	ND		ND		ND	
Spruce Heartwood	0.7	(1.6)	39.1	(10.3)	13.2	(2.4)	ND		ND		ND	

a. AWPA ratings and weight losses are six-sample means. Standard deviations are in parentheses.-
ND = Not done

3.5 Two-choice termite test

Results of the two-choice test, in which termites were presented with a choice of bark board or spruce heartwood, were consistent with those of the no-choice test (above). In all cases, the spruce heartwood wafers were severally damaged (visual ratings of 0, mass losses –ranging from 41-63%), while no bark board sample sustained a visual rating of less than 7, nor an individual mass loss greater than 11% (Table 3). When a more susceptible wood was available, there was clearly less termite feeding on all bark boards, including those veneered with pine or birch, than was the case in the no-choice tests where termites had no other option available.

Table 3. Percent Weight Loss of Non-Leached Bark Board and Spruce Heartwood plus Percent Mortality of Formosan Subterranean Termites in a Two-choice Test

Board Type	Bark board with or without veneer				Spruce heartwood					
	Mean AWPA Rating [a]		Mean % Weight Loss [a]		Mean AWPA Rating [a]		Mean % Weight Loss [a]		Mean % Mortality	
Bark board	8.5	(1.2)	5.9	(3.2)	0.0	(0.0)	50.9	(3.3)	20.5	(5.7)
Birch-veneer bark board	6.8	(1.6)	5.6	(2.9)	0.0	(0.0)	49.9	(7.1)	22.8	(2.2)
Pine-veneer bark board	7.3	(0.8)	3.8	(1.6)	0.0	(0.0)	46.8	(5.9)	22.4	(2.3)

a. AWPA ratings and weight losses are six-sample means. Standard deviations are in parentheses.

3.6 General discussion

These preliminary tests indicate that spruce bark board will perform well under conditions conducive to biological deterioration. The weight losses in the soil-block test would not be regarded as signifying complete decay resistance, but they are very good for a naturally durable forest product. Similarly, the soil-bed test results indicate a considerable degree of resistance to soft-rot fungi. Results of both the no-choice and two-choice termite tests indicate that termites avoid feeding on spruce bark board, although it was not extremely toxic to them. Leaching of the boards did not decrease their termite resistance. Spruce bark board thus appears to have a high degree of natural termite resistance. Some of the variability in the data in all these tests may be due to varying amounts of wood particles in the bark board samples. The natural resistance of bark board could be enhanced through screening out the wood particles, and, for termite resistance, additional treatment of the veneers. The original bark board material was not produced with the intention of assessing its natural durability, however, this attribute may well prove to be its major selling feature in domestic and overseas markets.

4 CONCLUSIONS

Spruce bark board is dimensionally stable and has considerable natural durability against brown rot, white rot, soft rot, and the Formosan subterranean termite.

This durability can be partially transferred into veneer in a one-step pressing process and is virtually unaffected by leaching.

More work will be required to fully define the natural durability of bark board, with and without veneer.

5 ACKNOWLEDGEMENTS

The authors would like to acknowledge the technical assistance of Jean Clark, Janet Ingram and Ken Chan of Forintek and Carrie Tome and Robert Oshiro of the University of Hawaii in carrying out these tests. Forintek Canada Corp would like to thank its industry members, Natural Resources Canada, and the Provinces of British Columbia, Alberta, Quebec, Nova Scotia and New Brunswick, for their guidance and financial support.

6 REFERENCES

1. American Wood Preservers= Association. 1998a. AWPA E1-97 Standard Method for Laboratory Evaluations to Determine Resistance to Subterranean Termites. AWPA, Granbury, TX, USA.

2. American Wood Preservers= Association. 1998b. AWPA E10-91 Standard Method of Testing Wood Preservatives by Laboratory Soil-Block Cultures. AWPA, Granbury, TX, USA.

3. American Wood Preservers= Association. 1998c. AWPA E14-94 Standard Method of Evaluating Wood Preservatives in a Soil-Bed. AWPA, Granbury, TX, USA.

4. Delate, K M and J K Grace. 1995. Susceptibility of neem to attack by the Formosan subterranean termite, *Coptotermes formosanus* Shir. (Isopt., Rhinotermitidae). Journal of Applied Entomology 119: 93-95.

5. Grace, J K 1997. Influence of tree extractives on foraging preferences of *Reticulitermes flavipes* (Isoptera: Rhinotermitidae). Sociobiology 30: 35-42.

6. Tamashiro, M., J.K. Fujii and P.Y. Lai. 1973. A simple method to observe,trap and prepare large numbers of subterranean termites for laboratory and field experiments. Environmental Entomology 2: 721-722.

7. Troughton, G E; K Chan and K Love. 1998. Manufacture of hog fuel board. United States Patent No. 5,725,818.