The performance of Accoya® and Tricoya® against attack by subterranean termites.

by

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Abstract

The resistance of high acetyl solid timber (Accoya®) and medium density fibreboard (Tricoya®) to attack by wood-destroying subterranean termites was investigated under both laboratory and field conditions. Laboratory studies were conducted in Japan and the USA. Field studies were conducted in Australia, Japan, Thailand and the USA. The results of the studies have improved knowledge of the resistance of acetylated wood to attack by subterranean termites; it has been demonstrated that Accoya® is highly resistant to attack by two species of the highly destructive *Coptotermes* genus and *Mastotermes darwiniensis*. It would be expected that Accoya® would exhibit excellent long-term performance against wood destroying subterranean termites in most regions in the world.

Keywords: Acetylation, Accoya®, Tricoya®, MDF, subterranean termites

Introduction

The acetylation of wood to improve its dimensional stability and durability has been studied for over 60 years (Tarkow *et al* 1946, Goldstein *et al* 1961, Peterson and Thomas 1978, Militz 1991, Bongers and Beckers 2003). Considerable research has been conducted to determine the effect of acetylation on the resistance of modified wood to fungal degradation (Peterson and Thomas 1978, Nilsson *et al* 1988, Rowell *et al* 1989, Takahashi *et al* 1989, Beckers *et al* 1994, Rowell *et al* 1997, Ohkoshi *et al* 1999, Suttie *et al* 1999, Birkinshaw and Hale 2002, Papadopoulos and Hill 2002, Hill *et al* 2006, Larsson-Brelid and Westin 2010), and there is generally good agreement that, at least above weight percent gains (WPG) of 20%, acetylated wood shows marked resistance to attack by most wood destroying fungi.

Compared with research on the resistance of acetylated wood to fungal decay, relatively few studies have been published on the resistance of acetylated wood to attack by wood destroying termites. Furthermore, those that have been published typically only contain data for a limited number of termite genera or species from a limited number of countries, and results are not all in agreement. In Japan, Imamura and Nishimoto (1986, 1987) investigated the resistance of three acetylated softwoods to attack by *Reticulitermes speratus* (Kolbe) and *Coptotermes formosanus* Shiraki. Acetylated timbers exhibited a high resistance to attack by *R. speratus* in both laboratory and field tests, whereas *C. formosanus* consumed up to 30% of acetylated spruce (20% WPG) in field tests. Papadopoulos *et al* (2008) investigated the resistance of acetylated Corsican pine to attack by *Reticulitermes flavipes* (Kollar) under laboratory conditions. They observed that a WPG of 16% significantly reduced wood consumption, but at 30% WPG there was apparently still appreciable attack and mass loss (ca. 7%). Rowell *et al* (1997) conducted field tests with acetylated composite board stakes in the USA and Indonesia. A WPG of 20% afforded acceptable protection against termite attack in most cases, even after a number of years' exposure; the species of termite present at the field sites was not reported.

Accsys Technologies has developed a commercial scale production process for the manufacture of high acetyl WPG solid timber (Accoya® wood) and has adapted its proprietary acetylation technology to enable the production of high acetyl wood elements (Tricoya® wood elements) for use within panel products such as MDF. The exploitation of Tricoya® is now carried out by Tricoya Technologies Limited, a joint venture between Accsys and INEOS Industries Holdings Limited. As part of its due diligence, the company has commissioned a number of laboratory and field studies around the world to assess the termite resistance of its products. The latest results from these studies are reported here.

Materials and methods

Laboratory testing

Laboratory termite bioassays were conducted in both Japan and the USA. In both cases the test termite used was *C. formosanus*.

Japanese test

The performance of Accoya® Radiata pine against attack by *C. formosanus* was evaluated in accordance with JIS K 1571 (2004). The performance of the Accoya® was compared with that of untreated radiata pine (*Pinus radiata* D. Don) and Japanese cedar (*Cryptomeria japonica* (L.f.) D. Don) sapwood. The test specimen size was 20 x 20 x 10 mm (thickness x width x length). Each test specimen was exposed to 150 workers and 15 soldiers in an individual container for 21 days. Any

dead termites were removed during the test period. Performance of the test materials against attack by *C. formosanus* was determined by measured mass loss. Any termite mortality at the conclusion of the test was also recorded. Two separate bioassays were conducted, one investigating the performance of Accoya® Radiata pine taken randomly from supplied samples, the other investigating the performance of Accoya® Radiata pine taken from the outer and inner portions of supplied samples.

USA test

A termite resistance test was performed in accordance with the AWPA E1-09 (2009). The choice method was used, consisting of leached and un-leached Accoya® Radiata pine, Accoya® Southern Yellow Pine (SYP), untreated radiata pine and SYP samples. Choice samples were comprised of SYP sapwood. Accoya® Radiata pine and untreated radiata pine samples were comprised of material grown in both New Zealand (NZ) and Chile. All test specimens measured 25 x 25 x 6.4 mm (thickness x width x length), and contained 4 to 6 growth rings per 25 mm. Five replicates of each sample type were included in the test. Each testing jar contained 150 g of autoclaved sand and 30 ml of distilled water. A test specimen was placed in each jar on top of the sand on an aluminium foil barrier to prevent any chemical leaching. Quantities of *C. formosanus* were aggregated and collected from the Brechtel State Park (Algiers, La) and 1.76 g of termites (400 individuals) were introduced into each jar on the side opposite the test specimen. The test duration was four weeks. Performance of the test materials against attack by *C. formosanus* was determined by measured mass loss and assignment of a visual rating. Any termite mortality at the conclusion of the test was also recorded.

Field testing

Australian test

The performance of Accoya® Radiata pine, Accoya® Beech, and Tricoya® medium density fibreboard (MDF) (manufactured from both radiata pine and spruce (*Picea* spp.) fibre) against attack by *Coptotermes acinaciformis* (Froggatt) and *Mastotermes darwiniensis* Froggatt was evaluated in Hazard Class H3 field trials. The performance of the acetylated materials was compared with that of the sapwood of untreated radiata pine and European beech (*Fagus sylvatica* L.), untreated exterior grade MDF, and the naturally durable heartwood of kwila (merbau) (*Instia bijuga* (Colebr.) Kuntze), spotted gum (*Corymbia maculata* (Hook.) K.D. Hill & L.A.S. Johnson), western red cedar (*Thuja plicata* Donn ex D.Don), American white oak (*Quercus alba* L.) and PNG Rosewood (*Pterocarpus indicus* Willd.). Solid timber test specimens had volumes of approximately 125 cm^3, MDF test specimens measured 105 x 100 x 12 mm.

The test methodology used was in accordance with that specified in the AWPC Protocols for Assessment of Wood Preservatives (2007). Prior to exposure in the field test specimens were first

leached in water for seven days, and then artificially weathered in vacuum ovens for five days at 40°C and 0.05 mBar to remove any residual volatiles. Test specimens were contained within stainless steel exposure chambers with equal volumes of susceptible bait-wood, the latter present in order to attract and maintain the presence of the target termite species. Exposure chambers were connected to active galleries of *C. acinaciformis* and *M. darwiniensis*, and removed from the field once all susceptible material had been consumed and termites had vacated the chambers; the exposure period was five months. Seven replicate test specimens of each sample were exposed in the field trials against seven different colonies of each termite species. The test site was located at Humpty Doo, Northern Territory, Australia.

Japanese test

The performance of Accoya® Radiata pine against attack by *C. formosanus* was evaluated in accordance with JIS K 1571 (2004) in an in-ground vertical stake field trial at a site located in the Kyushu region, Japan (it should be noted that the termite species *R. speratus* is also present at this location). The performance of the Accoya® was compared with that of untreated radiata pine. Untreated Japanese red pine (*Pinus densiflora* Siebold & Zucc.) sapwood stakes were included in the trial as susceptible bait-wood to attract termites into the test site. The test stakes measured 30 x 30 x 350 mm (thickness x width x length), and their condition was evaluated after one, two and four years' in-ground exposure using a visual rating system. Five replicate test specimens of each sample were exposed in the field trial.

Thailand test

The test was established in accordance with the AWPA E7-09 standard method of evaluating wood preservatives by field tests with stakes. The performance of Accoya® Radiata pine against attack by wood-destroying termites was evaluated in in-ground graveyard tests located at five different sites in Thailand. Teak (*Tectona grandis* L.f.) and makha (*Afzelia xylocarpa (Kruz.) Craib.*) were included as naturally durable reference timbers. Test specimen size was 90 x 22 x 470 mm (thickness x width x length). 20 replicates of each material were installed at each trial site in 2010. The condition of stakes in the test have been assessed regularly since they were installed, using an assessment scale similar to that described in ASTM D1758. The most recent inspection occurred after three years' exposure.

USA test

The test was established in accordance with the AWPA E7-09 standard method of evaluating wood preservatives by field tests with stakes. The performance of Accoya® Radiata pine (from both NZ and Chile) and Accoya® SYP against attack by wood-destroying termites was evaluated in in-ground graveyard tests located at two different sites, one in Gainesville, Florida (against *R. flavipes*)

and the other in San Luis, Costa Rica. Untreated stakes of each timber type were included in the test. The condition of the stakes was assessed after one and two years' exposure.

Results and discussion

Laboratory testing

Japanese test

Summaries of the mean mass losses for test materials exposed for 21 days in the laboratory against *C. formosanus*, together with observations on termite mortality, are given in Tables 1 and 2. Whilst the Accoya® wood materials were attacked by *C. formosanus* in the laboratory trial, the mass losses were low, being no greater than three percent. In contrast, the mass losses the untreated radiata pine and Japanese cedar samples were much higher, ranging from 10 to 30%. The mass losses of the outer and inner portions of the Accoya® Radiata pine sample were identical, which provides supporting evidence for uniform acetylation of the timber substrate through its cross-section.

Table 1: Mean mass losses and termite mortality for test specimens after exposure to *C. formosanus* in the laboratory test according to JIS K 1571 (2004) for 21 days (test 1).

Material Type	Mass Loss [%]	Termite Mortality [%]
Accoya® Radiata pine	3	21
Untreated Radiata pine	10	9
Japanese cedar	30	6

Table 2: Mean mass losses and termite mortality for test specimens after exposure to *C. formosanus* in the laboratory test according to JIS K 1571 (2004) for 21 days (test 2).

Material Type	Mass Loss [%]	Termite Mortality [%]	
		Worker	Soldier
Accoya® Radiata pine (outer portion)	3	6	93
Accoya® Radiata pine (inner portion)	3	6	99
Untreated Radiata pine	14	6	20
Japanese cedar	29	7	27

USA test

A summary of the mean mass losses and visual ratings for test materials exposed for four weeks in the laboratory against *C. formosanus*, together with observations on termite mortality, is given in Table 3.

All Accoya® wood materials were attacked by *C. formosanus* in the laboratory trial, with mass losses ranging from one to five percent. However, the mass loss was significantly lower than that incurred by the untreated radiata pine and southern pine samples, which ranged from 12 to 40%. The untreated choice test specimens were preferentially attacked in the jars containing the Accoya® test specimens, whereas the reverse was true in the jars containing the untreated radiata pine test specimens. Leaching did not appear to have a significant influence on the susceptibility of Accoya® materials to attack by *C. formosanus*. The visual ratings supported the mass loss data.

Table 3: Termite mortality and mean mass losses and visual ratings for test specimens after exposure to *C. formosanus* in the laboratory test (AWPA E1-09) for four weeks.

Material Type	**Leached / Un-leached**	**Mass Loss [%]**		**Visual Rating[a]**		**Mortality [%]**
		Treated	**Untreated Choice**	**Treated**	**Untreated Choice**	
Accoya® Radiata pine (Chile)	Leached	1	22	8.2	4.6	8
	Un-leached	3	18	7.2	4.0	10
Accoya® Radiata pine (NZ)	Leached	2	26	7.5	4.0	12
	Un-leached	3	26	7.4	4.7	10
Accoya® SYP	Leached	5	28	6.4	4.0	10
	Un-leached	4	25	7.0	4.6	7
Untreated Radiata pine (Chile)	Leached	34	5	4.0	7.7	10
	Un-leached	15	15	4.3	4.7	11
Untreated Radiata pine (NZ)	Leached	40	4	3.2	7.5	7
	Un-leached	35	9	0.8	7.7	12
Untreated SYP	Leached	13	18	7.1	6.4	10
	Un-leached	12	13	7.0	6.5	8
SYP Controls	Un-leached	26		0.5		10

[a] *10=Sound, surface nibbles permitted, 9=Light attack, 7=Moderate attack, penetration, 4=Heavy attack, 0=Failure*

Termite mortality after four weeks was similar and relatively low for all materials, being in the range 7-12%. There was no significant difference between the Accoya® wood samples and the untreated samples, regardless of whether they were leached or un-leached. This suggests that Accoya® does not have a toxic mode of action against wood destroying insects such as termites.

Field testing

Australian test

Summaries of the mean mass loss data for test materials exposed for five months in the Hazard Class H3 field trials are given in Tables 4 and 5. At the conclusion of the field trials, all test specimens within the exposure containers had evidence of contact by the target species of termite. All untreated bait-wood had been destroyed. The majority of the susceptible sapwood and exterior grade MDF test specimens were destroyed or severely attacked; against *C. acinaciformis*, the mean mass losses for each material type ranged from 74% to 95%, whilst against *M. darwiniensis* mean mass losses ranged from 95% to 100%. These mass losses, together with the destruction of the susceptible bait-wood, demonstrated that test specimens were subjected to a high level of termite pressure during the field trials.

Table 4: Mean mass loss of test specimens after exposure to *C. acinaciformis* in a Hazard Class H3 field trial (AWPC Protocols for Assessment of Wood Preservatives (2007)).

Material Type	**Mean mass loss [g]**	**Mean mass loss [%]**
Accoya® Radiata pine	0.31	0.5
Accoya® Beech	0.32	0.4
Tricoya® (radiata pine)	0.99	1.2
Tricoya® (spruce)	0.89	1.1
Radiata pine sapwood	41.01	82.6
Beech sapwood	71.22	94.6
Exterior grade MDF	64.56	74.3
Kwila heartwood	0.25	0.3
Spotted gum heartwood	1.25	1.0
Western red cedar heartwood	11.47	28.6

Table 5: Mean mass loss of test specimens after exposure to *M. darwiniensis* in a Hazard Class H3 field trial (AWPC Protocols for Assessment of Wood Preservatives (2007)).

Material Type	**Mean mass loss [g]**	**Mean mass loss [%]**
Accoya® Radiata pine	6.22	8.5
Accoya® Beech	1.33	1.6
Tricoya® (radiata pine)	2.99	3.5
Tricoya® (spruce)	3.97	3.8
Radiata pine sapwood	57.19	94.9
Beech sapwood	70.77	100.0
Exterior grade MDF	81.81	98.4
American white oak heartwood	108.77	99.8
Kwila heartwood	44.48	47.6
PNG Rosewood heartwood	36.48	48.9
Spotted gum heartwood	104.23	83.8
Western red cedar heartwood	27.40	69.3

The kwila and spotted gum heartwood test specimens were highly resistant to attack by *C. acinaciformis*, with mean mass losses of 0.3% and 1.0% respectively. In contrast, three of the seven western red cedar heartwood test specimens were significantly attacked, one being destroyed and a second largely destroyed. The mean mass loss for western red cedar was 28.6%. All of the Accoya® and Tricoya® materials performed similarly to kwila and spotted gum heartwood, having mean mass losses ranging from 0.4% to 1.2%. Any attack by *C. acinaciformis* largely consisted of minor localised grazing on the surfaces of test specimens.

All five of the naturally durable reference heartwood timber samples were significantly attacked by *M. darwiniensis*, with mean mass losses ranging from 48% to 100%. The kwila and PNG Rosewood samples were the most resistant to attack, whilst all of the American white oak test specimens were destroyed. The performance of the Accoya® and Tricoya® materials was markedly superior to that of all the naturally durable reference heartwood timber samples; mean mass losses ranged from 1.6% to 5.1%.

Japanese test

A summary of the mean ratings for test materials exposed for four years against *C. formosanus* in the vertical stake field trial is given in Table 6.

Table 6: Mean ratings for stakes after exposure to *C. formosanus* in the field (JIS K 1571) for four years.

Material Type	Rating[a]		
	1 Year	2 Years	4 Years
Accoya® Radiata pine	0	0	0
Radiata pine	46	76	100
Japanese red pine	Heavy attack	Heavy attack	Destroyed

[a]*0=Sound, 10=Shallow damage on surface, 30=Internal damage, 50=Widespread internal damage, 100=Collapse of stake.*

After four years' exposure in the field Accoya® stakes were in a sound condition. In contrast, the untreated radiata pine stakes and had been destroyed by *C. formosanus*. The Japanese red pine stakes had also been destroyed by *C. formosanus* after four years' exposure, demonstrating that test specimens were subjected to a high level of termite pressure during the field trial.

Thailand test

A summary of the mean termite ratings for test specimens after exposure in the in-ground graveyard tests at five sites for three years is given in Table 7. The Accoya® stakes exhibited evidence of slight nibbling by termites after three years' exposure. Teak was performing slightly worse, whilst makha was exhibiting significant levels of attack.

Table 7: Mean termite ratings for test specimens after exposure in the graveyard tests (AWPA E7-09) at five sites in Thailand for three years.

Material Type	Termite Rating[a]
Accoya® Radiata pine	9.6
Teak	8.8
Makha	6.0

[a]*10 = Sound, 0 = Complete failure*

USA test

A summary of the mean termite ratings for test specimens after exposure in the in-ground graveyard tests at two sites for two years is given in Table 8. At the Gainesville test site all untreated stakes had been destroyed after two years, whilst 20% of the Accoya® stakes had suffered minor nibbling or light attack, with the remainder being sound. At the San Luis test site more than half of

the untreated stakes had been destroyed, with the remainder having incurred moderate to heavy attack. In contrast, only one of the 30 Accoya® stakes had suffered minor nibbling, with the remainder being sound.

Table 8: Mean termite ratings for test specimens after exposure in the graveyard tests (AWPA E7-09) at two sites (Gainesville, Fl. and San Luis, Costa Rica) for two years.

Material Type	**Rating[a]**	
	Gainesville	**San Luis**
Accoya® Radiata pine (NZ)	10.0	10.0
Accoya® Radiata pine (Chile)	9.8	10.0
Accoya® SYP	9.7	10.0
Radiata pine (NZ)	0.0	2.7
Radiata pine (Chile)	0.0	1.8
SYP	0.0	3.2

[a]*10=Sound, surface nibbles permitted, 9=Light attack, 7=Moderate attack, penetration, 4=Heavy attack, 0=Failure*

Conclusions

The results of the laboratory and field studies have significantly improved knowledge of the resistance of acetylated wood to attack by subterranean termites. It has been demonstrated that Accoya® is highly resistant to attack by two species of the highly destructive *Coptotermes* genus and *M. darwiniensis*. It would be expected that Accoya® would exhibit excellent long-term performance against wood destroying subterranean termites in most regions in the world.

Acknowledgements

The laboratory study on the resistance of Accoya® to attack by *C. formosanus* was conducted by the Wood Durability Laboratory, Louisiana State University Agricultural Center. The Thailand field test was conducted by Environmental Research Centre, Faculty of Engineering, Naresuan University. Mathews Timber Pty Ltd (Vermont, Victoria 3133, Australia) supplied samples of Accoya® Radiata pine, radiata pine sapwood, and merbau, spotted gum, western red cedar, American white oak and PNG Rosewood heartwood for the Australian field trials. Medite Europe Ltd (Clonmel, Ireland) supplied samples of Tricoya® for the Australian field trials.

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