J Wood Sci (2007) 53:361–364
DOI 10.1007/s10086-006-0853-9

NOTE

Noriaki Katsumata · Tsuyoshi Yoshimura
Kunio Tsunoda · Yuji Imamura

Termite feeding preference to four wood species after gamma irradiation

Received: July 21, 2006 / Accepted: September 28, 2006 / Published online: February 9, 2007

Abstract The effect of gamma irradiation at 100 kGy and at lower levels on termite resistance was examined in the laboratory by no-choice and choice feeding termite tests (*Coptotermes formosanus* Shiraki) using four wood species: sapwood of *Cryptomeria japonica* D. Don, and heartwoods of *Pseudotsuga menziesii* (Mirbel) Franco, *Larix kaempferi* (Lambert) Carriere, and *Chamaecyparis obtusa* Endl. The wood consumption rates in *C. japonica* and *P. menziesii* specimens were likely to increase with increases in gamma-irradiation levels, whereas little effect of gamma irradiation was seen in *L. kaempferi* and *C. obtusa*. Similar results were obtained in the two-choice test. The current results indicated that in the two-choice test with *C. formosanus*, 100-kGy-irradiated *C. japonica* and *P. menziesii*, which are not rich in antitermite substances, were eaten more than other wood samples with or without gamma irradiation. However, only *C. japonica* showed significant difference in termite feeding activity. The mass loss in 100-kGy-irradiated *C. japonica* was significantly higher in the multichoice test.

Key words Gamma irradiation · *Coptotermes formosanus* Shiraki · Bait system

Introduction

It has been previously demonstrated that gamma irradiation corresponds with an increased intake by termites of *Cryptomeria japonica* D. Don.[1] Because the sapwood of *C. japonica* is known to have low termite resistance, it is not clear whether gamma irradiation enhances termite feeding in wood species that contain antitermite substances. The aim of this study was to clarify variations between different woods, treated and untreated, regarding termite feeding. Therefore, it was necessary to study differences in wood consumption rates when termites were fed with a variety of wood species that had been subjected to gamma irradiation.

Earlier studies supported the contention that the two-choice termite feeding test was an effective way to estimate the usefulness of the bait matrix,[2] the preferable feeding substances,[3] and antifeedant properties.[4,5] Doi et al.,[6] who tested steamed Japanese larch [*Larix kaempferi* (Lambert) Carriere] for its attractive property, suggested the feasibility of the choice termite feeding test using a laboratory nest.

In this study, the no-choice and two-choice termite feeding tests were conducted with four wood species to investigate termite feeding preferences. In addition, the multichoice test was performed with *C. japonica* using a laboratory nest of *Coptotermes formosanus* Shiraki in order to explore the relationship between gamma-irradiation levels and wood consumption mass losses.

Materials and methods

Test wood specimens

Air-dried sound sapwood of *Cryptomeria japonica*, heartwood of *Pseudotsuga menziesii* (Mirbel) Franco, *Larix kaempferi* (Lambert) Carriere, and *Chamaecyparis obtusa* Endl. were cut into small specimens measuring 10 (L) × 20 (R) × 20 (T) mm. Specimens of *C. japonica* that were prepared in the previous study[1] were used, and specimens of other wood species were newly gamma-irradiated at 1, 10, and 100 kGy. Gamma irradiation was performed with ^{60}Co at a radioactivity intensity of 5.6 PBq at the Koka Laboratory of the Japan Radioisotope Association. Three specimens each of 16 irradiation groups (4 wood species × 4 dose levels) were used for the no-choice termite feeding test. Another three specimens of each wood species at 0- and 100-kGy doses were used for the two-choice termite feeding test. Four specimens each of *C. japonica* gamma-irradiated at four dose levels (16 samples total) were prepared for the multichoice termite feeding test.

N. Katsumata (✉) · T. Yoshimura · K. Tsunoda · Y. Imamura
Research Institute for Sustainable Humanosphere, Kyoto University, Gokasyo, Uji, Kyoto 611-0011, Japan
Tel. +81-774-38-3663; Fax +81-774-38-3664
e-mail: katsumata@rish.kyoto-u.ac.jp

No-choice termite feeding test

A termite bioassay with *Coptotermes formosanus* Shiraki was conducted under forced feeding conditions according to JIS K 1571.[7] Wood specimens were weighed after drying at 60° ± 2°C for 3 days; then each of them was exposed to 150 workers and 15 soldiers in a test container. The container was maintained at 28° ± 2°C and greater than 85% relative humidity (RH) in darkness for 21 days. Following the feeding test, the amount of wood consumption was calculated from the difference in oven-dried weights of each sample before and after the test. Wood consumption rates were then determined by dividing the amount of wood consumption by the total days of exposure to worker termites during the exposure period, assuming that termite mortality increased linearly. The number of replications was three for each irradiation level. The obtained results for the different doses of gamma-irradiated specimens of each wood species were statistically analyzed by Tukey's test (inerSTAT-a v1.3[8]).

Two-choice termite feeding test

Wood specimens that were previously gamma-irradiated at 0 and 100 kGy were weighed after drying at 60° ± 2°C for 3 days and used for the two-choice termite test. A couple of both the irradiated and control specimens were placed in the same container with 150 workers and 15 soldiers. The assembled container was kept at 28° ± 2°C and greater than 85% RH for 5 days in darkness. After exposure, the percent wood mass loss was calculated from the difference in oven-dried weights of each sample before and after the test. Three replicates were tested for each wood species. The obtained results were statistically analyzed by the Student's *t*-test (inerSTAT-a v1.3[8]) for the untreated and the 100-kGy-irradiated specimens of wood species.

Multichoice termite feeding test

Gamma-irradiated *C. japonica* specimens with known oven-dried weights were randomly placed on a board (*Pinus densiflora* Sieb. et Zucc.) above a laboratory nest of *C. formosanus*. Four specimens with each dose, thus 16 samples, were arranged systematically to form a 14-cm square, 2 cm apart from each other. Specimens were exposed to termites at conditions of 28º ± 2°C and greater than 85% RH in darkness for 7 days. The percent mass loss of each wood specimen was calculated from the differences in oven-dried weights before and after the test. The obtained results were statistically analyzed by Tukey's test (inerSTAT-a v1.3[8]).

Results and discussion

No-choice termite feeding test

Figure 1 shows the result of the no-choice termite feeding test. Wood consumption rates for *Cryptomeria japonica* indicated the same tendency in our previous study.[1] They were not significantly different for the different irradiation treatments except in the case of the 100-kGy treatment (Tukey's test; $P < 0.01$). Similar results were obtained with *Pseudotsuga menziesii*; there was no significant difference. Wood consumption rates for *C. japonica* and *P. menziesii* specimens irradiated at 100 kGy were 1.6 and 1.4 times higher, respectively, than those of the untreated specimens. Because both *C. japonica* sapwood and *P. menziesii* heartwood are recognized as having low termite resistance,[9] it was expected that termite feeding activity on gamma-irradiated materials would be very similar.

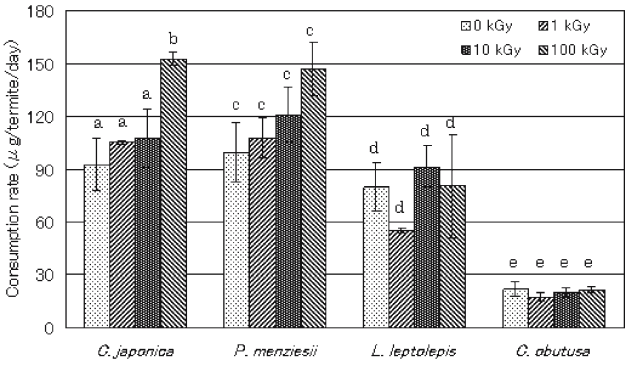

Fig. 1. Wood consumption rates of gamma-irradiated wood by *Coptotermes formosanus* in no-choice termite feeding tests. *Different letters* indicate significant difference (Tukey's test; $P < 0.01$). *Error bars* represent standard deviations

On the other hand, *Larix kaempferi* and *Chamaecyparis obtusa* heartwood are moderately resistant to termite attack.[9] There was no conspicuous effect of gamma irradiation on the levels of termite feeding. Termite feeding activity increased when flavonoid inside *L. kaempferi* was decomposed by steam treatment, and, as a result, a higher amount of steamed wood was taken by termites in comparison with the untreated wood.[4] On the other hand, the antifeedant substances of *L. kaempferi* such as flavonoid and 5-hydroxymethylfurfural were not negatively affected by gamma irradiation. This might also be true for *C. obtusa* containing α-cadinol, T-muurolol, and α-terpinyl acetate as antifeedant substances.[10–13] These results suggested that gamma irradiation did not cause any change in the chemical structures of antifeedant substances, whereas it contributed to a decrease in the degree of polymerization of cellulose in the wood cell wall.[1]

Two-choice termite feeding test

In the two-choice test, termites tend to attack the more susceptible substance of the two test materials.[14–16] It was quite natural that wood specimens of *C. japonica* gamma-irradiated at 100 kGy sustained more attack than untreated ones in this test. Termites showed a higher preference for 100-kGy-irradiated wood than for untreated wood, regardless of wood species, although the mass eaten by termites (milligrams per day) in the choice test did not differ much from that in the no-choice test (Table 1).

Table 1. Mass losses in nonirradiated and gamma-irradiated wood specimens by *Coptotermes formosanus* in two-choice and no-choice termite feeding tests

Specimen	0 kGy		100 kGy			
	Mass eaten by termites (mg)	Mass loss (%)	Mass eaten by termites (mg)	Mass loss (%)	Mass eaten by termites (mg)	Mass eaten by termites (mg/day)
Two-choice test					Overall[a]	
Cryptomeria japonica	5.67 ± 4.04	0.40 ± 0.29	90.33 ± 14.47**	6.21 ± 1.21	96.00	19.20
Pseudotsuga menziesii	28.00 ± 8.72	1.26 ± 0.41	104.67 ± 53.16	4.83 ± 2.58	132.67	26.53
Larix kaempferi	18.00 ± 1.73	1.00 ± 0.07	44.33 ± 18.85	2.39 ± 0.90	62.33	12.46
Chamaecyparis obtuse	19.00 ± 1.00	1.09 ± 0.07	26.33 ± 5.51	1.48 ± 0.30	45.33	9.07
No-choice test					Average[b]	
Cryptomeria japonica	293.00 ± 47.47	20.80 ± 2.73	481.00 ± 11.31	32.89 ± 0.47	387.00	18.43
Pseudotsuga menziesii	313.67 ± 54.22	17.55 ± 2.76	462.67 ± 47.71	26.18 ± 3.66	388.17	18.48
Larix kaempferi	251.67 ± 43.94	11.25 ± 2.09	252.33 ± 92.80	11.36 ± 4.30	252.00	12.00
Chamaecyparis obtusa	69.00 ± 13.08	3.92 ± 0.71	67.67 ± 5.51	3.91 ± 0.44	68.33	3.25

Data for 0 and 100 kGy irradiation given as mean ± standard deviation
** Student's *t*-test ($P < 0.01$)
[a] Total mass of two specimens eaten by termites
[b] Mean mass of 0 and 100 kGy specimens eaten by termites

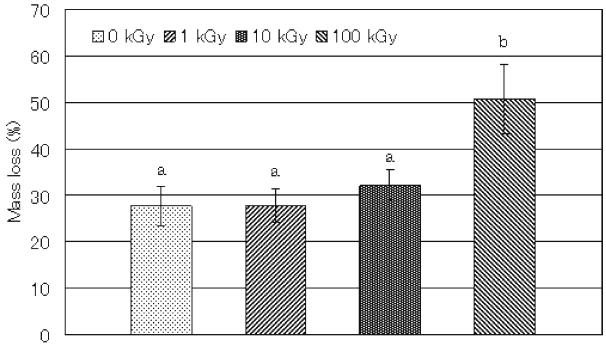

Fig. 2. Mass losses in gamma-irradiated sapwood specimens of *Cryptomeria japonica* in a multichoice termite feeding test by *Coptotermes formosanus*. *Different letters* indicate significant difference (Tukey's test; $P < 0.01$). *Error bars* represent standard deviations

Coptotermes formosanus workers showed a strong food preference, especially in the two-choice test. Comparison of the data of choice and no-choice tests seemed to indicate that *C. obtusa* was exceptionally significantly different. However, it is impractical to statistically analyze the data of overall masses eaten by termites per day in the choice and no-choice tests, because the original mother group in the no-choice test could not be defined.

Multichoice termite feeding test

As shown in Fig. 2, the mass loss of *C. japonica* sapwood increased with gamma-irradiation levels. The percent mass loss of 100-kGy-irradiated specimens was 50.7%, significantly higher than those at other irradiation doses (Tukey's test; $P < 0.01$). The current results clearly indicate that termites prefer wood specimens gamma-irradiated at high doses more than untreated wood or that gamma-irradiated at low doses.

Conclusions

Sapwood of *Cryptomeria japonica* and heartwood of *Pseudotsuga menziesii*, which are nondurable as regards biodegradation, became more susceptible to termite attack after gamma irradiation. This was clearly demonstrated by no-choice, two-choice, and multichoice termite feeding tests using *Coptotermes formosanus*. On the other hand, the effect of gamma irradiation was not seen for heartwood of *Larix kaempferi* and *Chamaecyparis obtusa*, which are rather durable and contain antifeedant substances. Consequently, when the gamma-irradiated wood species in the current tests are applied to bait system to suppress and/or control termite infestation, it is concluded that sapwood of *C. japonica* is the best as a bait matrix with attracting properties for termites. This is largely because of its ease of preparation and uniform quality compared with other wood species.

References

1. Katsumata N, Yoshimura T, Tsunoda K, Imamura Y (2007) Resistance of gamma-irradiated sapwood of *Cryptomeria japonica* to biological attacks. J Wood Sci DOI 10.1007/s10086-006-0852-x
2. Rojas MG, Morales-Ramos JA (2001) Bait matrix for delivery of chitin synthesis inhibitors to the Formosan subterranean termite (Isoptera: Rhinotermitidae). J Econ Entomol 94:506–510
3. Chen J, Henderson G (1996) Determination of feeding preference of Formosan subterranean termite (*Coptotermes formosanus* Shiraki) for some amino acid additives. J Chem Ecol 22:2359–2369
4. Ohmura W, Doi S, Aoyama M (2000) Antifeedant activity of flavonoids and related compounds against the subterranean termite *Coptotermes formosanus* Shiraki. J Wood Sci 46:149–153
5. Watanabe Y, Mihara R, Mitsunaga T, Yoshimura T (2005) Termite repellent sesquiterpenoids from *Callitris glaucophlla* heartwood. J Wood Sci 51:514–519
6. Doi S, Takahashi M, Yoshimura T, Kubota M, Adachi A (1998) Attraction of steamed Japanese larch [*Larix leptolepis* (Sieb. et Zucc.) Gord.] heartwood to the subterranean termite *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae). Holzforschung 52:7–12

7. Japanese Standards Association (2004) Japan Industrial Standard (JIS) K 1571. Test methods for determining the effectiveness of wood preservatives and their performance requirements. Japanese Standards Association, Tokyo
8. Vargas MH (1999) inarSTAT-a v1.3. Instituto Nacional de Respiratorias, Mexico
9. Ohmura W (2004) Wood industry handbook (in Japanese). Maruzen, Tokyo, p 795
10. Kinjo K, Doufuku Y, Yagi S (1988) Termiticidal substance from the wood of *Chamaecyparis obutusa* Endl. (in Japanese). Mokuzai Gakkaishi 34:451–455
11. Ohtani Y, Hazama M, Samejima K (1996) Crucial chemical factors for termiticdal activity of hinoki wood (*Chamaecyparis obutusa*) II. Variations in termiticidal activities among five individual samples of hinoki wood. Mokuzai Gakkaishi 42:1228–1233
12. Ohtani Y, Hazama M, Samejima K (1997) Crucial chemical factors for termiticidal activity of hinoki wood (*Chamaecyparis obutusa*) III. Contribution of α-terpinyl acetate to the termiticidal activity of hinoki wood. Mokuzai Gakkaishi 43:1022–1029
13. Ohmura W, Doi S, Aoyama M, Ohara S (1999) Components of steamed and non-steamed Japanese larch [*Larix leptolepis* (Sieb. et Zucc.) Gord.] heartwood affecting the feeding behavior of the subterranean termite, *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae). Holzforschung 53:569–574
14. Su N, Scheffrahn RH (1989) Comparative effects of an insect growth regulator, S-31183, against the Formosan subterranean termite and eastern subterranean termite (Isoptera: Rhinotermitidae). J Econ Entomol 82:1125–1129
15. Grace JK, Yamamoto RT, Tamashiro M (1992) Resistance of borate-treated Douglas-fir to the Formosan subterranean termite. Forest Prod J 42:61–65
16. Mauldin JK, Kard BM (1996) Disodium octaborate tetrahydrate treatments to slash pine for protection against Formosan subterranean termite and eastern subterranean termite (Isoptera: Rhinotermitidae). J Econ Entomol 89:682–688