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# Effect of hinoki (*Chamaecyparis obtusa*) wood-wool in tatami mat on the activity of house dust mite *Dermatophagoides pteronyssinus*

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**Abstract** To suppress the activity of house dust mites in tatami mats, where they tend to breed, a tatami mat consisting of hinoki (*Chamaecyparis obtusa*) wood-wool was prepared. The suppressive effect of hinoki wood-wool on house dust mites (*Dermatophagoides pteronyssinus*) was then measured. To investigate the effective period of the wood-wool on the mites, 5-day exposure tests were conducted every few weeks for a total of 52 weeks. In the tests of the first and sixth weeks, the activity of the mites was strongly suppressed, and no walking or moving mite was found after 5 days of exposure. The suppressive effect on mites was maintained for 52 weeks. It was concluded that using hinoki wood-wool to produce tatami mats is an effective method of suppressing the activity of mites for about 1 year.

**Key words** House dust mite · *Dermatophagoides pteronyssinus* · Wood-wool · Effective period · Volatiles

## Introduction

Many of the allergic diseases caused by house dust mites have recently become serious health problems,[1,2] and many reports have been published on the prevention of house dust mites. Recently, the effect of essential oils of plants on house dust mites has received much attention with a view to producing natural mite-killing agents,[3–8] replacing insecticides. Essential oils of wood and their leaves have also received much attention. Miyazaki et al.[9] summarized the effects of 27 leaf oils from various genera on the activity of *Dermatophagoides pteronyssinus* according to plant genus. Leaf oils from the genus *Thuja* and *Eucalyptus* had strong influences on mites. The effects of *Picea*, *Abies*, *Thujopsis*, and *Juniperus* oils on mites were moderate. *Pinus* and *Chamaecyparis* oils had slight influence on the mites as compared with the oils of other genera used in their experiment. Leaf oils of hinoki-asunaro (*Thujopsis dolabrata* var. *hondai*), tabunoki (*Machilus thunbergii*), urajiromomi (*Abies homolepis*), *Eucalyptus citriodora*, Norway Spruce (*Picea abies*), tsuga (*Tsuga sieboldii*), and sawara (*Chamaecyparis pisifera*) had strong activity on *Dermatophagoides farinae*.[10–12] Leaf oils of shirodamo (*Neolitsea sericea*) and hinoki (*Chamaecyparis obtusa*) had acaricidal activity against *D. farinae* and *D. pteronyssinus*.[11,13]

For wood oil, Yatagai et al.[14] and Morita et al.[15] showed that yakusugi (a variety of *Cryptomeria japonica*) wood oil and yakusugi bogwood oil had strong activitiy on *D. pteronyssinus*. Wood oils from Douglas fir (*Pseudotsuga douglassi*), western redcedar (*Thuja plicata*), hiba (*Thujopsis dolabrata* var. *hondai*), and hinoki are known to strongly suppress the activity of *D. pteronyssinus* and *D. farinae* and the effect of sugi (*Cryptomeria japonica*) oil on the activity of the mites is considered moderate.[9,16] Oribe and Miyazaki[17] showed that wood oils of *Chamaecyparis taiwanensis* and hiba at concentrations exceeding 0.2% significantly suppressed population growth of *D. pteronyssinus*. Chang et al.[18] reported that *Taiwania cryptomerioides* essential oil was effective in exterminating *D. pteronyssinus*.

Thus, some studies have reported the effects of leaf and wood oils on house dust mites, but there are few studies on the effects of volatiles directly from wood. Enomoto et al.[19] used eastern redcedar (*Juniperus virginiana*) balls (diameter 7 mm) and chips, and showed that their volatiles repelled *D. farinae*. Hiramatsu and Miyazaki[20] showed that volatiles from hiba, hinoki, and kusunoki (*Cinnamomum camphora*) chips strongly suppressed the walking and moving of *D. pteronyssinus*. Aiming at practical use of wood for

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the control of house dust mites, Mori and Miyazaki[21] prepared tatami mats embedded with softwood veneers and examined the suppressive effect of volatiles from the veneers on *D. pteronyssinus*. They found that the volatiles from the hiba and hinoki veneers strongly suppressed the walking and moving of the mites, and that sugi moderately suppressed these activities. In addition, Hiramatsu and Miyazaki[22] showed that the volatiles from hiba and hinoki veneers suppressed the activity of the mites for 54 weeks and 11 weeks, respectively. Thus, it is important to examine the effective period of volatiles for their practical use. In this study, to maintain the suppressive effect on the mites and to extend the effective period, tatami mats were produced using hinoki wood-wool and the effective period of the wood-wool in the tatami mats on *D. pteronyssinus* was measured.

## Materials and methods

### House dust mites

Adult female house dust mites, *Dermatophagoides pteronyssinus* (Acari: Pyroglyphidae), that were cultivated in a mixture of powdered animal food (CE-2; Clea, Japan) (50%) and dry yeast (Ebios; Asahi Beer Pharmaceutical) (50%) culture media, were used for the exposure test.

### Tatami mats

Two tatami mats (Hinoki Tatami; Hida Forest) consisting of hinoki (*Chamaecyparis obtusa*) wood-wool, lauan veneers, hemp cloths, and vinylon strings were used for the exposure test. The mat sizes were $400 \times 400$ mm and 60 mm thick, and the density was about 0.23 g/cm$^3$. Wood-wool for tatami mats was produced by a wood-wool shredding machine (MG-20; Inamoku) from hinoki logs (diameter about 200 mm), which were harvested in Gifu, Japan, in April 2004 and were kept in a room without air conditioning for about 1 month. The size of the wood-wool was about 5 mm in width, 0.1–0.3 mm in thickness, and 50–400 mm in length. The wood-wool was dried to about 10% moisture content in a drying oven (Makabe) at a temperature of 40°C for 10 h. Tatami mats were made from the wood-wool by a roll press (Kyouei) and a sewing machine. No adhesive was used. The thickness of the tatami mats was controlled by the spacing of the roller presses.

One tatami mat was soaked in 75% ethanol solution for 5 days and dried for 10 days twice to remove extractives from the hinoki wood-wool, and this tatami mat was used as a control sample. The other tatami mat was not treated, and is called hinoki tatami in this study. The two tatami mats were kept in a room with air conditioning at 23°C and 60% relative humidity (RH) for 1 week before the exposure tests.

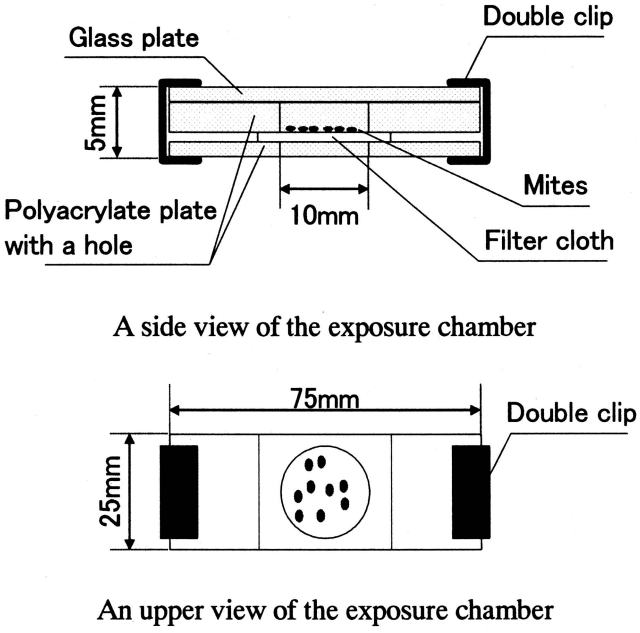


**Fig. 1.** Illustrations of the exposure chamber for testing the effect of volatiles from hinoki (*Chamaecyparis obtusa*) wood-wool in a tatami mat on house dust mites

### Exposure test

The exposure chambers (Fig. 1), which were modified versions of the rearing containers used by Matsumoto et al.,[23] were made the same as in the studies of Hiramatsu and Miyazaki.[20,22]

The tatami mat had six cavities for arranging the chambers in their regular positions. The chambers were covered with hinoki wood-wool wrapped with paper towels. To investigate the suppressive effect of volatiles from hinoki wood-wool on the activity of the mites, a 5-day exposure test was conducted. Six exposure chambers were placed in the tatami mat (Fig. 2). The control tatami mat and no tatami mat were used as control samples.

The degree of activity of the mites was classified into two categories: (1) walking and moving (legs, chelicerae, pedipalpi, etc.) and (2) immobilized. The activity of the mites was monitored by microscope every day. The difference between values was analyzed by the Student's *t*-test, and was considered significant when the *P* value was less than 0.01 or 0.05 compared with the control tatami mat. The tests were conducted in desiccators ($500 \times 500 \times 500$ mm). The cavities in the tatami mats where the chambers were placed were conditioned to about 25°C and 70%–80% RH using a saturated KCl solution.

To investigate the effective period of the suppressive effect of hinoki wood-wool, 5-day exposure tests were conducted every few weeks for a total of 52 weeks (Fig. 3). New exposure chambers were prepared at the start of each 5-day exposure test, and the mites in the culture media were placed in them. The same tatami mats were used. They were kept in a controlled room at a temperature of 23°C and 60% RH, except during the exposure test period. The difference

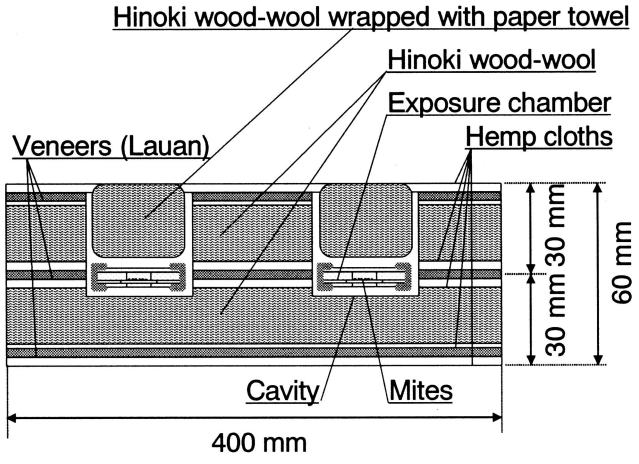


**Fig. 2.** Illustration of the cross section of the tatami mat consisting of hinoki (*Chamaecyparis obtusa*) wood-wool (hinoki tatami)

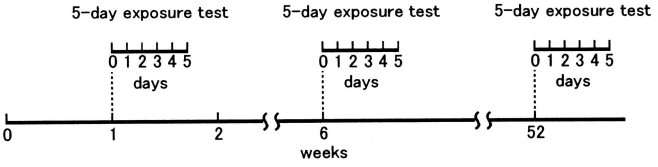


**Fig. 3.** The method of investigating the effective period of volatiles from hinoki (*Chamaecyparis obtusa*) wood-wool in the tatami mat on the activity of mites. In each 5-day exposure test, the activity of mites was measured every day of the exposure. Exposure tests were conducted every few weeks for 52 weeks

between values was analyzed by the Student's *t*-test, and was considered significant when the *P* value was less than 0.01 or 0.05 compared with the control tatami mat. The exposure tests were conducted from June 2004 to June 2005.

## Results

The percentages of walking and moving *Dermatophagoides pteronyssinus* after 5 days of exposure for each 5-day exposure test are shown in Fig. 4. The percentages of walking and moving mites were 60%–67% in the control tatami mat and 62%–80% with no tatami mat in each exposure test, and a significant difference was not seen. The activity of the mites was strongly suppressed in the hinoki tatami mat consisting of the hinoki wood-wool in all tests up to the 52nd week, and a significant difference from the control tatami ($P < 0.01$ or $P < 0.05$) was seen. The suppressive effect gradually decreased over time. However, in the test of the 52nd week, the effect was still strong and 62% of the mites were immobilized, and a significant difference from the control tatami mat ($P < 0.05$) was seen.

In the 5-day exposure test, the activity of the mites was measured every day. The results of the 5-day exposure test of the 6th, 17th, 33rd, and 52nd weeks are shown in Fig. 5.

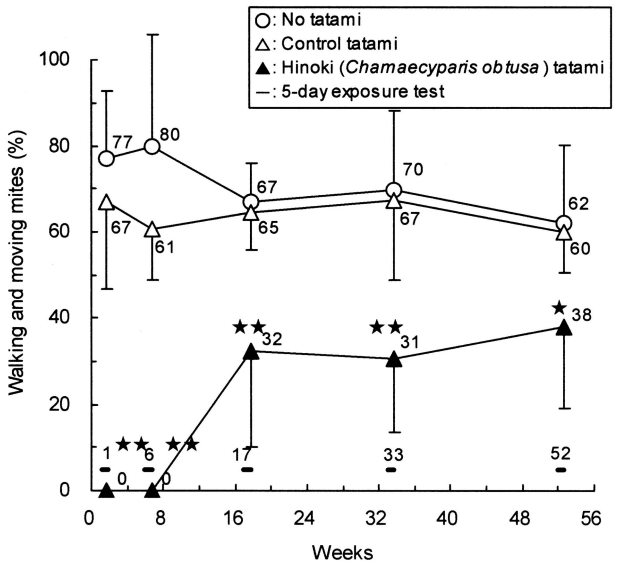


**Fig. 4.** The percentage of walking and moving mites after 5 days of exposure to volatiles from hinoki (*Chamaecyparis obtusa*) wood-wool in the tatami mat. Significant difference from the control tatami mat is marked with a *star* ($P < 0.05$ by Student's *t*-test) or *double stars* ($P < 0.01$ by Student's *t*-test). Standard deviations are marked with *bars*

The suppressive effect of volatiles from hinoki wood-wool on the activity of the mites was strong in the test of each week. In the tests of the 1st and 6th weeks, the percentages of walking and moving mites decreased to 8% and 10%, respectively, after 3 days of exposure. After 5 days of exposure, no walking or moving mite was found. In the tests of the 17th, 33rd, and 52nd weeks, the percentages of the walking and moving mites decreased to 57%, 65%, and 60%, respectively, after 3 days of exposure; and after 5 days of exposure, they decreased to 32%, 31%, and 38%, respectively.

## Discussion

In each exposure test, the effects of the control tatami mat and no tatami mat on *Dermatophagoides pteronyssinus* were almost the same and a significant difference was not seen, indicating volatiles from the control tatami mat, which had been soaked in 75% ethanol solution to remove the extractives, did not have the suppressive effect on the mites. On the other hand, in the hinoki tatami mat, the activity of the mites was strongly suppressed, indicating volatiles from hinoki wood-wool in the tatami mat had the suppressive effect on the mites.

In the test of the first week, hinoki wood-wool in the tatami mat strongly suppressed the activity of *D. pteronyssinus*. In other studies, the effects of hinoki wood oil, chips, and veneers on the mites were examined. Miyazaki et al.[9] examined the suppressive effect of hinoki wood oil (100 $\mu$l over 234 $cm^2$) on the activity of *D. pteronyssinus*, and showed that hinoki wood oil strongly

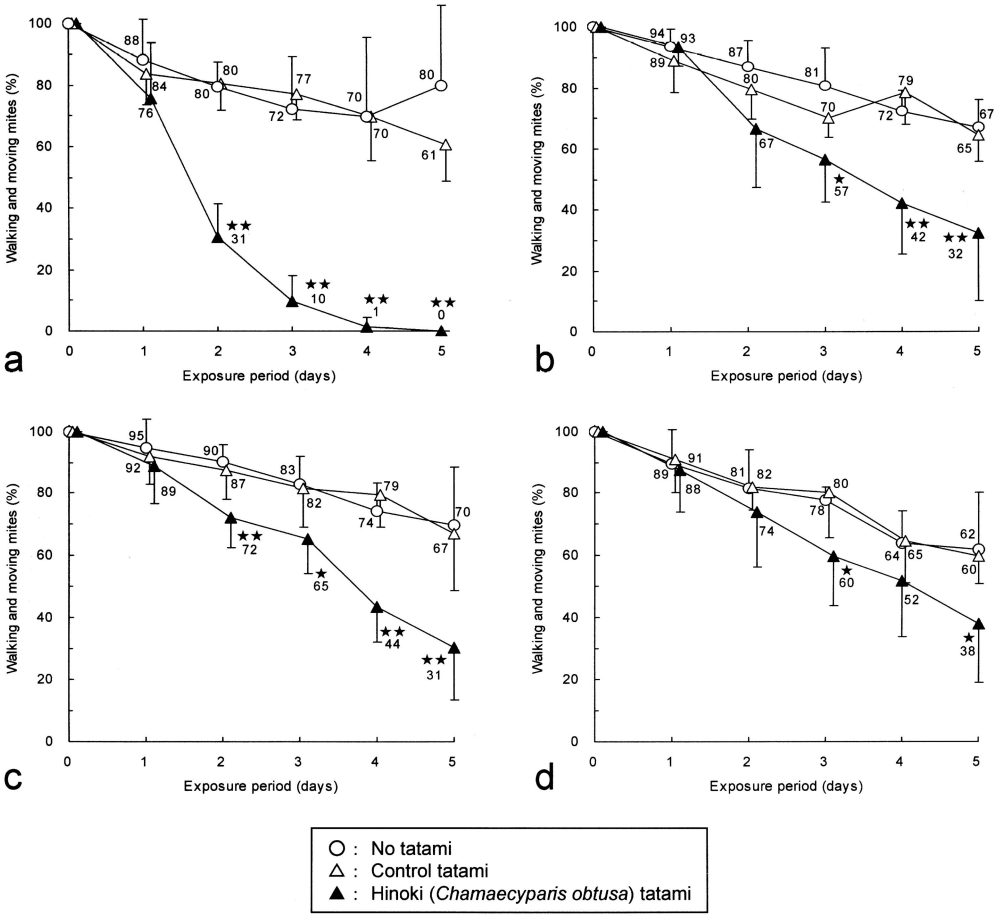


**Fig. 5a–d.** Changes in the activity of mites during 5-day exposure tests of the 6th (**a**), 17th (**b**), 33rd (**c**), and 52nd (**d**) week to volatiles from hinoki (*Chamaecyparis obtusa*) wood-wool in the tatami mat. Significant difference from the control tatmi mat is marked with a *star* ($P < 0.05$ by student's *t*-test) or *double stars* ($P < 0.01$ by Student's *t*-test). Standard deviations are marked with *bars*

suppressed the mites' activity. Yamamoto et al.[24] prepared carpet cleaners containing wood oil extracted from hinoki and examined the effect on the activity of *D. pteronyssinus*. They found that hinoki wood oil had a suppressive effect on the mites at 0.1% concentration. Hiramatsu and Miyazaki[20] showed that the volatiles from hinoki wood chips strongly suppressed the activity of *D. pteronyssinus*. Mori and Miyazaki[21] embedded hinoki veneers in tatami mats and examined the suppressive effect of volatiles from the veneers on *D. pteronyssinus*. They showed that the volatiles from hinoki veneers strongly suppressed the activity of the mites, and embedding hinoki veneers in tatami mats is useful in controlling mites.

From these experiments, it appeared that hinoki wood volatiles had a suppressive effect on the activity of house dust mites for a short time. However, it is also important to examine the effective period of volatiles to control the mites for longer periods. Morita et al.[25] prepared microcapsules from hinoki oil by a spray-dry method, and examined the effective period of volatiles from the microcapsules on the activity of *D. pteronyssinus*. They showed that the microcapsules made from hinoki oil retained antimite activity for 6 months. Hiramatsu and Miyazaki[22] conducted the 5-day exposure test, as used in the present study, to examine the effective period of volatiles from hinoki veneers embedded in tatami mat. They showed that volatiles from hinoki veneers in tatami mat suppressed the activity of *D. pteronyssinus* for 11 weeks. In their test, in the exposure test of the 54th week, the suppressive effect of hinoki was low, with no significant difference from the control being observed. On the other hand, in the present study, in the test of the 52nd week, the effect of hinoki wood-wool in the tatami mat was strong, and 62% of the mites were immobilized. The hinoki tatami mat was mainly composed of wood-wool, and the amount of wood used was about 10 times that used in the hinoki veneers embedded in the tatami mat. The surface area of the wood-wool was also larger, so the volatiles from hinoki wood-wool in the tatami mat were highly effective in suppressing the mites' activity, compared with those from the embedded hinoki veneers. However, using hinoki wood-wool and hinoki veneers to produce tatami mats are both effective measures for suppressing the activity of the mites.

If wood volatiles are to be used in daily life, in addition to their effect on mites, their influence on human comfort should be considered. In this study, the influence of volatiles from hinoki wood-wool on humans was not examined, but the influence of wood oils and volatiles on humans has been investigated in other studies. In some studies, sensory evaluations were conducted to investigate the psychological effects of the smell of hinoki, and these showed that the smell of hinoki was considered to be natural, refreshing,

vivacious, and rich and imparted intellectual feelings.[20,24,26] In addition, recently it was reported that the odorous stimuli of $\alpha$-pinene and limonene, which are volatiles of wood, both decreased systolic blood pressure and induced comfortable feelings in humans.[27,28] These results suggested that the smell of wood is comforting to human beings. However, the influence of the long-term exposure of humans to wood volatiles is not clear at present, and this should be examined. There is not enough basic data on the influence of wood oils and volatiles on humans, and further research is called for. Moreover, advances in research in collaboration with other fields, such as medicine, will become important in the future.

In conclusion, the activity of house dust mites was suppressed in tatami mat consisting of hinoki wood-wool for 52 weeks. This suggests that using hinoki wood-wool to produce tatami mats is effective for prevention of the mites, and the suppressive effect of tatami mats consisting of wood-wool can be maintained for longer periods by adjusting their sizes, increasing the amount of wood-wool, and using wood-wool from other kinds of wood that strongly suppress the activity of house dust mites (e.g., hiba).

## References


1. Voorhorst R, Spieksma-Boezeman MIA, Spieksma FTM (1964) Is a mite (Dermatophagoides sp.) the producer of the house-dust allergen? Allergie und Asthma 10:329–334
2. Wharton GW (1976) House dust mites. J Med Entomol 12:577–621
3. Ottoboni F, Rigamonti IE, Lozzia GC (1992) House dust mites prevention in Italy. Boll Zool agr Bachic Ser 2 24:113–120
4. McDonald LG, Tovey ER (1993) The effectiveness of benzyl benzoate and some essential plant oils as laundry additives for killing house dust mites. J Allergy Clin Immun 92:771–772
5. Tovey ER, McDonald LG (1997) A simple washing procedure with eucalyptus oil for controlling house dust mites and their allergens in clothing and bedding. J Allergy Clin Immun 100:464–466
6. Kim EH, Kim HK, Ahn YJ (2003) Acaricidal activity of clove bud oil compounds against *Dermatophagoides farinae* and *Dermatophagoides pteronyssinus* (Acari: Pyroglyphidae). J Agr Food Chem 51:885–889
7. Lee HS (2004) *p*-Anisaldehyde: acaricidal component of *Pimpinella anisum* seed oil against the house dust mites *Dermatophagoides farinae* and *Dermatophagoides pteronyssinus*. Planta Med 70:279–281
8. Lee HS (2004) Acaricidal activity of constituents identified in *Foeniculum vulgare* fruit oil against *Dermatophagoides* spp. (Acari: Pyroglyphidae). J Agr Food Chem 52:2887–2889
9. Miyazaki Y, Yatagai M, Takaoka M (1989) Effect of essential oils on the activity of house dust mites. Jpn J Biometeor 26:105–108
10. Asada T, Ishimoto T, Sakai A, Sumiya K (1989) Insecticidal and antifungal activity in hinoki-asunaro leaf oil (in Japanese). Mokuzai Gakkaishi 35:851–855
11. Furuno T, Terada Y, Yano S, Uehara T, Jodai S (1994) Activities of leaf oils and their components from Lauraceae trees against house dust mites. Mokuzai Gakkaishi 40:78–87
12. Miyazaki Y (1996) Differences in susceptibilities of mites (*Dermatophagoides farinae* and *Tyrophagus putrescentiae*), found in house dust, to exposures to several leaf oils. Mokuzai Gakkaishi 42:523–533
13. Jang YS, Lee CH, Kim MK, Kim JH, Lee SH, Lee HS (2005) Acaricidal activity of active constituent isolated in *Chamaecyparis obtusa* leaves against *Dermatophagoides* spp. J Agr Food Chem 53:1934–1937
14. Yatagai M, Miyazaki Y, Morita S (1991) Extractives from yakusugi bogwood and their termicidal activity and growth regulation effects on plant seeds (in Japanese). Mokuzai Gakkaishi 37:345–351
15. Morita S, Yatagai M, Ohira T (1991) Antimite and antifungal activities of the hexane extractive from yakusugi bogwood (in Japanese). Mokuzai Gakkaishi 37:352–357
16. Miyazaki Y (1996) Effect of hiba wood oil on the house dust mite. Mokuzai Gakkaishi 42:624–626
17. Oribe Y, Miyazaki Y (1997) Effects of two wood oils on the population growth of the European house-dust mite, *Dermatophagoides pteronyssinus*. Mokuzai Gakkaishi 43:521–523
18. Chang ST, Chen PF, Wang SY, Wu HH (2001) Antimite activity of essential oils and their constituents from *Taiwania cryptomerioides*. J Med Entomol 38:455–457
19. Enomoto T, Ohnishi S, Dake Y, Shibano A, Sakoda T, Saitoh Y, Sogoh H, Yamana T, Matsui K (1999) Environmental control for allergic diseases—avoiding and killing effect on house dust mite by eastern red cedar (in Japanese). Jpn J Allergol 48:626–631
20. Hiramatsu Y, Miyazaki Y (2001) Effect of volatile matter from wood chips on the activity of house dust mites and on the sensory evaluation of humans. J Wood Sci 47:13–17
21. Mori T, Miyazaki Y (2002) Effect of softwood thin veneers in tatami on the activity of house dust mite *Dermatophagoides pteronyssinus*. J Wood Sci 48:163–164
22. Hiramatsu Y, Miyazaki Y (2004) Effective period of volatiles from softwood veneers embedded in tatami mats on the activity of house dust mites. J Wood Sci 50:217–222
23. Matsumoto K, Okamoto M, Wada Y (1986) Effect of relative humidity on life cycle of the house dust mites, *Dermatophagoides farinae* and *D. pteronyssinus*. Jpn J Sanit Zool 37:79–90
24. Yamamoto N, Miyazaki Y, Sakuda K (1998) Sensory evaluation of carpet cleaner containing essential oil and the effect on mites. J Wood Sci 44:90–97
25. Morita S, Nakamura S, Murata S, Okumura K (1993) Microcapsulation of essential oils and their antimite activity (in Japanese). Wood Industry 48:265–269
26. Miyazaki Y, Yatagai M, Kobayashi S (1993) Sensory evaluation of essential oils and their components (in Japanese). Mokuzai Gakkaishi 39:843–848
27. Morikawa T, Tsunetsugu Y, Miyazaki Y (2005) The effect of the odorous stimuli of $\alpha$-pinene on autonomic nervous activity, cerebral activity, and sensory evaluation (in Japanese). In: Abstracts of the 55th Annual Meeting of the Japan Wood Research Society, Kyoto, p 82
28. Morikawa T, Tsunetsugu Y, Miyazaki Y (2005) The effect of the odorous stimuli of limonene on autonomic nervous activity, cerebral activity, and sensory evaluation (in Japanese). In: Abstracts of the 55th Annual Meeting of the Japan Wood Research Society, Kyoto, p 192