Chemical Analyses of the Dead Wood Eaten by the Larvae of *Ceruchus lignarius* and *Prismognathus angularis* (Coleoptera: Lucanidae)

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The contents of chemical components (alkaline extractives, ethanol/benzene extractives, holocellulose and lignin) were determined for the dead wood in which the larvae of *Ceruchus lignarius* (brown rot specialist) or *Prismognathus angularis* (decay type generalist) occurred. The variations of chemical components were small in the samples of *C. lignarius* and relatively large in those of *P. angularis*. It was established that *C. lignarius* occurred exclusively in the brown rotten wood in advanced stage of decay, whereas the occurrence of *P. angularis* was not as clearly associated with either decay type or its stage.

Key words: chemical components, wood decay, lucanid larvae

INTRODUCTION

Decayed-wood feeders had been regarded as rather euryphagous in contrast with living- or stressed-wood feeders which have a remarkable specificity for food trees (see ROBERT and SLANCKY, 1985 for review). Recently, on the basis of the pattern of occurrence of the lucanid larvae (Coleoptera: Lucanidae) in dead wood, ARAYA (1993) showed that some lucanid species appeared to be stenophagous for decay type. (Since lucanid larvae seem unable to move freely from one wood piece to another, their occurrence pattern in dead wood must be a result of the parental oviposition pattern.) However, the previous study was based on macroscopic observations only. Chemical analyses are needed to precisely identify the decay type and stage of dead wood. Thus, in the present study, the contents of alkaline extractives, ethanol/benzene extractives, holocellulose and lignin were determined for the dead wood in which the lucanid larvae of *Ceruchus lignarius* or *Prismognathus angularis* occurred.

MATERIALS AND METHODS

Lucanid species. *C. lignarius* is a brown rot specialist, whereas *P. angularis* is a decay type generalist (ARAYA, 1993). These species are similar in body size (about 1.5 to 2.5 cm in length) and similar distribution range (the cool temperature zone) in Japan.

Samples. Collection of decayed wood was carried out in the winter of 1989 in the secondary broad-leaved forest (Inabu-chô, northeastern Aichi Prefecture) dominated by the Japanese beech (*Fagus crenata* BLUME) and the Japanese oak (*Quercus mongolica*

FISCH). Six pieces of dead wood in which the larvae of *C. lignarius* were found and seven which contained *P. angularis* were collected randomly. The wood species were identified by macro- and microscopic observation of the structure, such as bark, pore and ray (SAIKI, 1982; SAIKI and HARADA, 1985). The decay types were identified by macroscopic observation (KIRK and COWLING, 1984).

Pretreatment of determination. A small wood piece was taken from the vicinity of a larva in the collected dead wood. The wood samples were air-dried and ground to pass through 40 mesh (pore size 420 μm) but not through 80 mesh (pore size 177 μm). The contents of alkaline extractives, ethanol/benzene extractives, holocellulose and lignin were determined. I followed the SCHORGER's Method (PETTERSEN, 1984; YASUDA, 1985) for the procedures of determination, including the pretreatment. All the results were presented as a percentage of the moisture-free sample weight.

Alkaline extractives. Alkaline extractives were calculated from the weight loss after refluxing with 1% sodium hydroxide solution for one h at 100°C. These include extraneous components (protein, pectin, tannin, etc.), low molecular weight lignin and hemicellulose.

Ethanol/benzene extractives. Ethanol/benzene extractives were extracted with ethanol/benzene (1:2 in volume) in the Soxhlet Extractor under reflux for six h. These include pigment, oil, decay-resistant substance, etc.

Holocellulose. Total holocellulose contents were determined using the ethanol/benzene extractives free wood meal by the chlorite method (PETTERSEN, 1984; YASUDA, 1985).

Lignin. Total lignin contents were determined also using the ethanol/benzene extractives free wood meal. I followed the modified hydrolysis method of MARILYN (1977) and determined Klason lignin (acid-insoluble lignin).

Comparisons of variances for each component. After the percentages of alkaline extractives, ethanol/benzene extractives, holocellulose and lignin were transformed to their arcsine-square root, variances for the transformed data for the samples of *C. lignarius* and of *P. angularis* were compared.

Comparison. The contents of alkaline extractives and holocellulose determined in the present study were compared with those of the typical brown rotten wood (the Japanese beech which are attacked by the brown rot fungus, *Tyromyces palustris*) and with those of the typical white rotten wood (the Japanese beech which are attacked by the white rot fungus, *Coriolus versicolor*). TAKAHASHI (1986) was referred to for the compared data: contents of alkaline extractives and holocellulose of typical brown and white rotten wood in the various decay stages.

RESULTS

Dead wood

As shown in Table 1, the six pieces of dead wood in which *C. lignarius* larvae occurred comprised two brown rotten Japanese beeches (*Fagus crenata*), three brown rotten Japanese oaks (*Quercus mongolica*) and one Japanese oak whose decay type could not be determined by macroscopic observation. The seven pieces of dead wood in which *P. angularis* larvae occurred comprised four pieces of white rotten Japanese beech, two of white and one of brown rotten Japanese oak. The developmental stage of the lucanid larvae in each sample is also shown in Table 1.

Table 1. The results of macroscopic identification of tree species and decay type and determination of chemical components in the wood samples

Lucanid species	Tree species	Stage of lucanid larvae	Decay types in appearance	Alkaline extractives ^a (%)	EtOH/Benzene extractives (%)	Holo-cellulose ^b (%)	Lignin ^c (%)
<i>C. lignarius</i>	<i>Fagus crenata</i>	3rd	B. R.	78.5	3.9	16.9	71.9
	<i>Fagus crenata</i>	3rd	B. R.	76.5	4.0	16.0	66.5
	<i>Quercus mongolica</i>	3rd	B. R.	77.8	5.4	17.0	65.6
	<i>Quercus mongolica</i>	3rd	B. R.	81.7	3.4	15.9	68.6
	<i>Quercus mongolica</i>	3rd	B. R.	77.4	4.0	16.4	67.1
	<i>Quercus mongolica</i>	2nd	N. C.	69.0	4.2	18.8	58.5
<i>P. angularis</i>	<i>Fagus crenata</i>	3rd	W. R.	22.5	3.4	54.9	29.4
	<i>Fagus crenata</i>	3rd	W. R.	50.7	1.6	24.3	48.5
	<i>Fagus crenata</i>	3rd	W. R.	33.4	1.6	45.8	23.8
	<i>Fagus crenata</i>	3rd	W. R.	33.8	2.1	40.6	37.9
	<i>Quercus mongolica</i>	3rd	W. R.	33.9	1.5	47.5	22.9
	<i>Quercus mongolica</i>	3rd	W. R.	28.1	1.7	31.9	26.3
	<i>Quercus mongolica</i>	3rd	B. R.	72.3	4.1	17.4	65.0

3rd=third (final) instar; 2nd=second instar; B. R.=brown rot; W. R.=white rot.; N. C.=not classified.

^a Significantly different between *C. lignarius* and *P. angularis* (test for homogeneity of variance, $p<0.05$).

^b Significantly different at $p<0.001$.

^c Significantly different at $p<0.05$.

Alkaline extractives

All the samples of *C. lignarius* contained large amounts of alkaline extractives (69.0 to 81.7%). In the samples of *P. angularis*, one piece of brown rotten wood contained abundant alkaline extractives (72.3%), whereas the other six pieces of white rotten wood contained significantly less (22.5 to 50.7%). The variance of the samples of *C. lignarius* was significantly smaller than that of *P. angularis* (test for homogeneity of variance, $F=28.07$, $p<0.05$).

Ethanol/benzene extractives

The contents of ethanol/benzene extractive varied from 3.4 to 5.4% in the samples of *C. lignarius*, and from 1.5 to 4.1% in the *P. angularis* samples. There was no difference between the variances of the samples of *C. lignarius* and of *P. angularis* (test for homogeneity of variance, $F=14.41$, $p>0.05$).

Holocellulose

The holocellulose contents in all the *C. lignarius* samples was markedly low (15.9 to 18.8%). In the *P. angularis* samples, the minimum holocellulose content was obtained from the brown rotten wood (17.4%), whereas in the other pieces of white rotten wood

Fig. 1. The contents of alkaline extractives and holocellulose of the dead wood in which the lucanid larvae occurred, compared with those of the typical brown (attacked by *Tyromyces palustris*) or white rotten (attacked by *Coriolus versicolor*) wood of Japanese beech in the various decay stages (data from TAKAHASHI, 1986). □ : classified as white rot by macroscopic observation; ○ : classified as brown rot by macroscopic observation; △ : not classified; open symbols: samples of *Ceruchus lignarius*; closed symbols: samples of *Prismognathus angularis*; — : typical brown rot; ----- : typical white rot. Numbers on the lines represent the decay stages, measured as total weight loss of moisture-free wood (%).

its content was larger (24.3 to 54.9%). The variance of the samples of *C. lignarius* was significantly smaller than that of *P. angularis* (test for homogeneity of variance, $F=15.00$, $p<0.001$).

Lignin

The lignin content of all the *C. lignarius* samples was large (58.5 to 71.9%). In the *P. angularis* samples, one piece of brown rotten wood also contained it in abundance (65.0%), whereas the other white rotten pieces contained less of it (23.8 to 48.5%). There was a significant difference between the variances of the samples of *C. lignarius* and of *P. angularis* (test for homogeneity of variance, $F=20.38$, $p<0.05$).

Comparison

As shown in Fig. 1, the contents of alkaline extractives and holocellulose in all the samples of *C. lignarius* corresponded to those of the brown rotten wood whose decay stage was advanced (total weight loss 40 to 50%). The one piece of brown rotten wood with the samples of *P. angularis* was also in the category of the brown rotten wood whose decay stage was well advanced (total weight loss about 45%), and the other six wood pieces with *P. angularis* corresponded to the pieces of white rotten wood in various stages of decay (total weight loss 20 to 60%).

DISCUSSION

Since the contents of alkaline extractives and holocellulose in the decayed wood

change in a characteristic fashion depending on both decay type and stage, they are often used for precise identification of both factors (STAMM, 1964; BROWNING, 1975; HARAGUCHI, 1982; PETTERSEN, 1984; TAKASHI, 1986).

The previous study (ARAYA, 1993) showed, on the basis of macroscopic identification of decay type, that *C. lignarius* was a brown rot specialist and *P. angularis* was a decay type generalist. In the present study this conclusion was more precisely confirmed in terms of the contents of chemical components. Furthermore, the present study also revealed that *C. lignarius* is stenophagous for both the decay stage and for the decay type, whereas *P. angularis* is euryphagous.

Lucanid larvae seem unable to move freely from one native wood piece to another, and it takes two years or more for the larvae of both *C. lignarius* and *P. angularis* to finish their development (ARAYA and ÔBUCHI, 1992; ARAYA, personal observation). In the present study, however, the decayed wood pieces were sampled cross-sectionally only once in the winter. Therefore, it is unknown how fast the decay stage progresses relative to the length of larval developmental period in the wild. Longitudinal studies will be necessary to learn how wide the range of the decay stages is that the lucanid larvae actually experience throughout their whole developmental period.

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