Purchased by the Forest Products Laboratory,
U.S. Department of Agriculture, For Official Use Only

Catabolism of Aspen Sapwood in *Reticulitermes flavipes* (Isoptera: Rhinotermitidae)[1]

G. R. ESENTHER AND T. K. KIRK
Forest Products Laboratory, Forest Service,
U.S. Department of Agriculture,
Madison, WI 53705

The only investigation of the quantitative changes in principal components of wood by our most destructive native subterranean termite genus, *Reticulitermes,* resulted in a questionably high depletion of the lignin (Seifert and Becker 1965). Moreover, nitrogen balance has not been established for metabolism of wood by *Reticulitermes.* This paper reports attack on aspen sapwood (*Populus grandidentata* Michx.) by *Reticulitermes flavipes* (Kollar) and chemical analysis of the principal wood components and nitrogen in the termite-wood system.

Reticulitermes flavipes was collected at Janesville, Wis., July 1973, and maintained ca. 2 months before use. Eighteen extractive-free (Kirk and Moore 1972) aspen sapwood wafers (initially 0.3×2.5×2.5 cm, large face cross-sectional) were exposed to termites. Before exposure, ¼ of each wafer was removed and these were combined for initial chemical analysis of the wood. Each of the remaining wafers (0.3×1.8×2.5 cm) was placed with 1.0 g of functional worker termites (avg 300 apterous and 62 wing-padded forms; 4th instars and older) in cylindrical plastic boxes (5.0×3.5 cm) for 4 wk. Nine wafers were moistened with distilled water to 50% moisture content ("dry" condition) and 9 to 150% ("wet" condition) (dry wt basis). The "wet" condition was included in an attempt to favor bacterial attack on the feces; it was thought that bacterial attack might have been responsible for the high digestion of lignin reported previously. Incubation was at 26°C and 70% RH. At 2- to 3-day intervals termite mortality was noted and water added when necessary to maintain the approximate original moisture content.

The termites ingested most of the wood during the 4-wk exposure, (85 and 67% for dry and wet conditions, respectively), leaving fecal residue on the floor and walls of the boxes. This residue was visually dry in the dry condition and wet in the wet condition (Fig. 1). Cannibalism was observed in all boxes. After exposure the termites and uneaten wood and fecal residues were oven-dried, weighed (Table 1), and analyzed (Table 2).

Whereas the termites fed and survived at both "dry" and "wet" conditions (Table 1), the high moisture condition seems near the upper limit of moisture tolerance since 3 termites apparently drowned. Also, survival and amount of wood eaten were lower in the "wet" condition, and soldier termites developed only in the dry condition.

Termite mortality, almost entirely by cannibalism, was

FIG. 1.-Illustration of the wet (center) and dry moisture situations during exposure of aspen wafers to *R. flavipes* attack, and box with unexposed aspen wafer. Notice the water film in the wet condition.

[1] Received for publication June 13, 1974.

Table 1.—Average results of 4-wk exposure of aspen wafers to *R. flavipes* at 2 moisture conditions.

WOOD Condition	Moisture Content (%) Initial	Final	Fecal residue	Weight (mg) [b,c] Ingested	Fecal residue	Digested[d] %
"dry"	50	42	66	530	168	68
"wet"	150	176	413	428	135	68

TERMITES wood condition	Group Composition[e] Initial W	Initial N	Final W	Final N	Final S	Survival %	Live weight (mg) Initial	Live weight (mg) Final
"dry"	303	22	210	44	5	74	1000	795
"wet"	296	66	161	61	0	61	1000	664

[a] Nine replicates per condition.
[b] Equilibrium 27 C and 70% RH.
[c] Original average weight = 627 mg (dry condition) and 651 mg (wet condition)
[d] $\frac{\text{(Weight ingested - weight fecal residue)}}{\text{weight ingested}} \times 100.$
[e] W, workers (apterous); N, nymphs (wing pads) ; S, soldiers.

mainly at the expense of workers at both moisture conditions (Table 1). (Esenther [1969] observed that such cannibalism is not always primarily at the expense of the workers in situations with certain caste form compositions.)

Percentage catabolism of ingested wood was the same 2). Methods used in chemical analyses and calculations of glucan, mannan, etc. are described elsewhere (Seamen et al. 1954, Hiller et al 1948, Kirk and Highley 1973).

Comparison of the chemical composition of the original wood with that of the fecal residues revealed essentially no change in the amount of ("sulfuric acid") lignin. for the 2 moisture conditions (Table 1). This similarity also extended to changes in chemical composition (Table Termites generally appear to have a low lignin degrading ability (Leopold 1952, Noirot and Noirot-Timothée 1969). The high lignin digestion (77%) by *Reticulitermes lucifugus* var. *santonensis* Feytaud reported by Seifert and Becker (1965) was associated with an abnormal coprophagic situation and complete mortality of the termites.

Table 2.—Percentage chemical composition of wood, residues, and termites (dry wt basis).

Material	Percentage Glucan	Mannan	Xylan	Lignin	OMe	N[a]
Control wood[b]	47.0	2.4	21.3	17.2	22.2	0.06
Uneaten wood (dry)	44.9	2.3	20.9	20.0	21.6	0.09
(wet)	45.3	2.4	20.3	19.5	20.9	0.20
Fecal residue (dry)	12.6	1.7	10.4	56.7	20.7	0.85
(wet)	12.5	1.6	10.7	56.4	20.9	0.86
Termites (dry)	—	—	—	—	—	2.59
(wet)	—	—	—	—	—	2.82

[a] Live (wet) wt basis. Original termites had 2.61% N (13.3% on dry wt basis).
[b] Control wood maintained 4 wk wet (≀150%, H_2O) or dry (≀50%, H_2O) gave same analyses.

Therefore, the Seifert and Becker results are not representative of the lignin-degrading ability of *Reticulitermes.*

Our analysis indicated a slight (5%) loss in the methoxyl content of the lignin, which may, however, reflect contamination of the "sulfuric acid" lignin by non-lignin materials (see Sarkanen and Ludwig 1971, p. 8). Even though not depleted or significantly demethylated, the lignin was changed on passage through the termites. This was shown by the results of acidolysis (refluxing 4 h in 0.2 N HCl in 90% dioxane: H_2O; Lundquist 1970) of the fecal residue (dry condition), as compared to the original wood. Less than half as much of the principal aromatic product, 3-(3,5-dimethoxy-4-hydroxyphenyl)-1-hydroxy-2-propanone (estimated by gas chromatography), was obtained from the lignin in the fecal residue (2.7 vs 7.5%; see Kirk et al. 1974). The 2nd major product obtained from hardwood lignins, l-hydroxy-3-(4-hydroxy-3-methoxyphenyl)-2-propanone, was not separated well from other products in the residue and could not be estimated accurately. It was obvious, however, that the 2nd product was also obtained in a much lower amount than from the control wood.

Loss of glucan (mainly cellulose), calculated from the data in Tables 1 and 2, on passage through the termites was 91% in both the wet and dry conditions. Similarly, loss of the major hemicellulose, measured as xylan, was 84%, and loss of the mannan-type hemicellulose was 77 and 76% in the 2 situations. Clearly, then, (anaerobic) catabolism of the polysaccharides of aspen wood in R. *flavipes* is efficient.

The principal difference between the wet and dry conditions was simply that the ingestion was slowed by the higher moisture content. It was suspected that some differences might result either from differences in gut flora or from enhanced (aerobic) bacterial activity in the wet residue. A simple dilution plate count on nutrient agar revealed, as expected, a much higher bacterial population in the wet residue, but the bacteria had little quantitative effect (Table 2).

The N determinations (Table 2) and weight data in Table 1 were used to calculate the N balance in the termite-wood systems. It was suspected that an overall in-

crease in N might be observed, because Breznak et al. (1973) reported bacterial N-fixation in *Reticulitermes.* However, even with relatively high N content of fecal residues and uneaten wood, net loss in total weight of termites, with their high N contents, more than compensated; there was actually an overall loss of N from the systems (17% wet condition; 23%, dry condition).

We presume that the loss of N from the system was dietary N (cannibalized termites and ingested wood) which was excreted. Mullins and Cochran (1972) reported that N is excreted mainly as NH_5 by a cockroach, and this also may be true for *R. flavipes;* loss of NH_3 to the air could account for the N loss observed here.

Termites apparently rely on cannibalism when they are restricted to a nutritionally deficient diet (Moore 1969). Therefore, our results showing 26 and ca. 39% cannibalism indicate that the extracted aspen sapwood was a nutritionally deficient diet for termites, in spite of the reported ability of their gut flora to fix N_2.

REFERENCES CITED

Breznak, J. A., W. J. Brill, J. W. Mertins, and H. C. Coppel. 1973. Nitrogen fixation in termites. Nature (Lond.) 244: 577–80.

Esenther, G. R. 1969. Termites in Wisconsin. Ann. Entomol. Soc. Am. 62(6): 1274–84.

Hiller, A., J. Plazin, and D. D. Van Slyke. 1948. A study of conditions for Kjeldahl determination of nitrogen in proteins. J. Biol. Chem. 176: 1401.

Kirk, T. K., and W. E. Moore. 1972. Removing lignin from wood with white-rot fungi and digestibility of resulting wood. Wood and Fiber 4: 72–9.

Kirk, T. K., and T. L. Highley. 1973. Quantitative changes in structural components of conifer woods during decay by white- and brown-rot fungi. Phytopathology 63: 1338–42.

Kirk, T. K., and H-m. Chang. 1974. Decomposition of lignin by white-rot fungi. Characterization of heavily degraded lignins from decayed spruce. Holzforschung (In press).

Kirk, T. K., H-m. Chang, and L. F. Lorenz. 1974. Topochemistry of fungal degradation of lignin in birch wood as related to the distribution of guaiacyl and syringyl lignins. Wood Sci. and Technol. (In press).

Leopold, B. 1952. Studies on Lignin: XIV. The composition of Douglas fir wood digested by the West Indian drywood termite (*Cryptotermes brevis* Walker). Svensk Papperstidn. 55: 784–6.

Lundquist, K. 1970. Acid degradation of lignin. II. Separation and identification of low molecular weight phenols. Acta. Chem. Scand. 24: 889–907.

Moore, B. P. 1969. Biochemical studies in termites. Pages 410 *in* K. Krishna and F. M. Weesner, ed. Biology of termites, vol. 1. Academic Press, New York and London. 598 pp.

Mullins, D. E., and D. G. Cochran. 1972. Nitrogen excretion in cockroaches: uric acid is not a major product. Science (Wash., D. C.) 177: 699–701.

Noirot, C., and C. Noirot-Timothée. 1969. Page 77 *in* K. Krishna and F. M. Weesner, ed. Biology of termites, vol. 1. Academic Press, New York and London. 598 pp.

Saeman, J. F., W. E. Moore, R. L. Mitchell, and M. A. Millet. 1954. Techniques for the determination of pulp constituents by quantitative paper chromatography. Tappi 37: 336.

Sarkanen, K. V., and C. H. Ludwig, eds. 1971. Lignins: occurrence, formation, structure, chemical and macromolecular properties and utilization. Wiley-Interscience, N. Y. 916 pp.

Seifert K., and G. Becker. 1965. Der chemische Abbau von Laub- und Nadelholzarten durch verschieden Termiten, Holzforschung 19(4): 105–11.

Reprinted from the

ANNALS OF THE ENTOMOLOGICAL SOCIETY OF AMERICA

Volume 67, Number 6, pp. 989-991, November 1974