Action of Soft Rot- and White Rot Fungi on Partially Delignified Softwoods*

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Abstract——Fourty-four species of softwoods were partially delignified with acidified sodium chlorite for 6 hours at 40°C and exposed to a soft rot fungus, *Chaetomium globosum* KUNZE, for 8 weeks at 28°C. The weight losses after the chlorite treatment considerably varied with species. The lowest weight loss was 1.6 % for *Chamaecyparis obtusa* and the highest was 21.9 % for *Larix gmelini*. The weight losses after the exposure to *Ch. globosum* noticeably increased in proportion to the degree of delignification. The highest weight loss was 58.2 % for *Picea glehnii* and the lowest was 6.2 % for *Chamaecyparis obtusa*. Furthermore, the pattern of acceleration of wood decay by the chlorite treatment has been studied for two softwoods and one hardwood, with reference to the decrease of total lignin content, using *Ch. globosum* and a white rot fungus, *Coriolus versicolor* QUÉL. The results showed that the effect of delignification was positively observed in all woods for both fungi but considerably varied with wood and fungal species. In the case of *Pinus densiflora*, the maximum level of wood decay was reached at about 43 % of delignification for *Ch. globosum* and at greater stage of delignification for *Co. versicolor*. In *Cryptomeria japonica*, the maximum level was at 50 % or more for *Ch. globosum* and at about 18 % for *Co. versicolor*. Maximum levels in both woods for *Ch. globosum* were higher than those for *Co. versicolor*, in spite of lower attacking capacity of the former on original woods. In *Fagus crenata*, highly susceptible to both fungi, acceleration was not greater than in the two softwoods.

Introduction

Soft rot- and white rot fungi prefer hardwoods to softwoods but the former have lower capacity to degrade lignin as brown rot fungi. Although brown rot fungi are associated most frequently with the decay of softwoods containing higher amount of lignin than hardwoods, they have a limited capacity to degrade lignin. Many investigators have been interested in the significance of the different host-wood preference and different lignin-degrading ability in the three types of wood-decaying fungi. Satisfactory explanation for these respects are not obtained yet. BAILEY *et al.*[1] and NOUVERTNÉ[2] found that the delignification with acidified sodium chlorite increased the weight loss of softwood by soft rot fungi. In their investigations, determination of lignin was not carried out and loss of lignin by the treatment was roughly estimated from the original lignin content found in a literature. Furthermore, the observation was done only at one or few stages of delignification. In the

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present investigation, effect of the chlorite delignification of softwoods on the wood-decaying capacity of soft rot- and white rot fungi has been studied at various stages of delignification.

Materials and Methods

Wood

The names of 44 softwood- and 1 hardwood timber species used in the experiment are listed in Table 1. Sampling of wood specimen was made from the intermediate portion of heartwood, considering the well established trend of increasing decay resistance from the innermost to the outermost heartwood[3,4]. Wood specimens were used in two forms: (1) 2.0 (tangential) × 2.0 (radial) × 0.5 (longitudinal) cm blocks; (2) 0.3 mm thick longitudinal shavings cut to about 4 mm in the fiber direction. Wood blocks were prepared from all of the species and used in the decay tests. Shavings were used in the lignin determination and taken from the three species only (Nos. 19, 36 and 45, see Table 1.).

Partial delignification

The partial delignification of the wood specimens was carried out with sodium chlorite and acetic acid.

The specimens were extracted with ethanol-benzene (1 : 2) for 24 hours and soaked in warm water (50°C) for 4 hours before chlorite treatment.

Wood blocks:

The specimens, separately bound to the teflon plate with fine teflon strings, were placed in a beaker containing sodium chlorite (70 g $NaClO_2$/30 g wood/litre solution) and acetic acid (30 ml). The solutions were maintained at 40°C and stirred slowly throughout the treatment by a magnetic stirrer. Six blocks from each wood species were treated for 6 hours. On the three wood species (Nos. 19, 36 and 45), in addition, sets of 6 blocks from each species were treated for different lengths of time, 24 hours at the longest.

Wood shavings:

The specimens were placed in a beaker containing the solution with the same charge of chemicals as mentioned above. Batches of 1 g of wood were treated for different lengths of time under the same condition. After the chlorite treatment, the wood specimens were rinsed in running water, and air-dried before drying to constant weight in an oven at 105°C.

Lignin determination

The Klason lignin content was determined by the JIS P 8008-1961. The acid-soluble lignin content was determined on the hydrolysate from the Klason lignin

Table 1. Timber species used in the experiment.

No.	Botanical name	Common name	
		Japanese	English
1	*Ginkgo biloba* L.	Icho	Maidenhair tree
2	*Taxus cuspidata* SIEB. et ZUCC.	Ichii	Japanese yew
3	*Torreya nucifera* SIEB. et ZUCC.	Kaya	Japanese Torreya
4	*Podocarpus macrophylla* D. DON	Inumaki	Longleaf Podocarp
5	*Podocarpus nagi* ZOLL. et MORITZ.	Nagi	Nagi Podocarp
6	*Cephalotaxus harringtonia* K. KOCH	Inugaya	Japanese plum yew
7	*Abies firma* SIEB. et ZUCC.	Momi	Japanes fir
8	*Abies mariesii* MAST.	Aomoritodomatsu	Maries' fir
9	*Abies sachalinensis* FR. SCHM.	Todomatsu	Sachalin fir
10	*Abies sachalinensis* FR. SCHM. var. *mayriana* MIYABE et KUDO	Aotodomatsu	(Fir, Spruce)
11	*Pseudotsuga japonica* BEISSN.	Togasawara	Japanese Douglas fir
12	*Tsuga sieboldii* CARR.	Tsuga	Japanese hemlock
13	*Picea glehnii* MAST.	Akaezomatsu	Glehn's spruce
14	*Picea jezoensis* CARR.	Ezomatsu	Yezo spruce
15	*Picea abies* KARST.	Doitsutohi	Spruce
16	*Larix leptolepsis* GORD.	Karamatsu	Japanese larch
17	*Larix gmelini* LEDEB.	Guimatsu	Kurile larch
18	*Keteleeria davidiana* BEISSN.	Yusan	Abura-sugi
19	*Pinus densiflora* SIEB. et ZUCC.	Akamatsu	Japanese red pine
20	*Pinus pentaphylla* MAYR.	Himekomatsu	Japanese white pine
21	*Pinus thunbergii* PARL.	Kuromatsu	Japanese black pine
22	*Pinus tabulaeformis* CARR.	Manshukuromatsu	Manchurian pine
23	*Pinus radiata* D. DOM	Radiatamatsu	Montrey pine
24	*Pinus rigida* MILL.	Rigidamatsu	Black pine
25	*Pinus taeda* L.	Tedamatsu	Torchpine
26	*Piuus sylvestris* L.	Oshuakamatsu	Scots pine
27	*Pinus nigra* ARN.	Oshukuromatsu	Corcican black pine
28	*Pinus strobus* L.	Sutorobumatsu	White pine
29	*Pinus virginiana* MILL.	Bajiniamatsu	Virginia pine
30	*Pinus elliotti* ENGELM.	Eriottimatsu	American pitch pine
31	*Sciadopitys verticillata* SIEB. et ZUCC.	Koyamaki	Umbrella pine
32	*Sequoia sempervirens* ENDL.	Sekoia	Redwood
33	*Metasequoia glyptostroboides* HU et CHENG	Metasekoia	Dawn redwood
34	*Glyptostrobus pensilis* K. KOCH	Suisho	Swamp cypress
35	*Taxodium distichum* RICH.	Numasugi	Bald cypress
36	*Cryptomeria japonica* D. DON	Sugi	Japanese cryptomeria
37	*Cunninghamia konisii* HAYATA	Randaisugi	Formosa fir
38	*Taiwania cryptomerioides* HAYATA	Taiwansugi	Taiwania
39	*Chamaecyparis obtusa* ENDL.	Hinoki	Japanese cypress
40	*Chamaecyparis pisifera* ENDL.	Sawara	Sawara cypress
41	*Chamaecyparis formosensis* MATSUM.	Benihi	Formosan cypress
42	*Thuja standishii* DARR.	Nezuko	Japanese arbor-vitae
43	*Thujopsis dolabrata* SIEB. et ZUCC.	Asunaro	Hiba arbor-vitae
44	*Juniperus virginiana* L.	Enpitsubyakushin	Eastern red cedar
45	*Fagus crenata* BULME	Buna	Japanese beech

by measuring ultraviolet absorption at 205 nm in 1 cm quartz cells in a Shimadzu MPS-50 spectrophotometer. Fulfural and hydroxymethyl fulfural are formed on the acid treatment of carbohydrates under the conditions of hydrolysis used[5]. How-

ever, these aldehydes give a sharp absorption maximum at about 280 nm, but relatively low absorbance at shorter wavelengths (205~210 nm)[5]. Several investigators[6,7,8] have reported that measurement of absorbance at a wavelength in the region of 200~210 nm provides a reasonable measure of soluble lignin in wood. Usually, the amount of soluble lignin should be determined as compared with some standard lignin preparations. However, some preparations, such as modified or degraded products derived from the original lignin during chlorite treatment, may have an unknown and fluctuating absorptivity[5]. Hence, accepting that determination of soluble lignin in chlorited preparations based on ultraviolet absorbance can be considered only as approximations, the absorptivity used is 110 g^{-1} 1 cm^{-1} for all batches of the three species according to MUSHA and GORING[9]. The acid-soluble lignin content was calculated as follows[5]:

$$\% \text{ acid-soluble lignin} = \frac{(A_s - A_b) \times V}{110 \times W} \times 100$$

where A_s is the absorbance of the sample, A_b is the absorbance of the blank, W is the weight of the sample in g, and V is the volume in litres of the solution.

Test fungi

Mostly, a soft rot fungus, *Chaetomium globosum* KUNZE (Strain No. 8059) was used as a test fungus. For the purpose of comparison, a white rot fungus, *Coriolus versicolor* QUÉL. (No. 1030) was occasionally used.

Decay tests

The decay tests were carried out by the sand-block method. Cylindrical glass bottles (9 cm in diameter and 16 cm in height), containing 350 g of quartz sand (ca. 30 mesh) and 120 ml of nutrient solution, were screwed with metal caps. The bottles were autoclaved and inoculated with the test fungi which were allowed to cover the surface of the medium before the test blocks were inserted. Three blocks each in two bottles were used in each species or each series of partial delignification.

The composition of the nutrient solution is as follows:

for the decay test using *Ch. globosum*,

NH_4NO_3 3.0 g, KH_2PO_4 2.5 g, K_2HPO_4 2.0 g, $MgSO_4 \cdot 7H_2O$ 2.0 g, glucose 25.0 g and distilled water 1000 ml.

for the decay test using *Co. versicolor*,

KH_2PO_4 3.0 g, $MgSO_4 \cdot 7H_2O$ 2.0 g, peptone 5.0 g, malt extract 10.0 g, glucose 25.0 g and distilled water 1000 ml.

The weighed test blocks were sterilized by fumigation with propylene oxide, and exposed to test fungi. Test blocks for the decay test using *Ch. globosum* were soaked in sterilized distilled water after the fumigation, since soft rot fungi have a

Table 2. Decay resistance of 45 timber species against *Ch. globosum* after partial chlorite delignification (6 hours at 40°C).

No.*	Weight loss by chl. treatment (%)**	Weight loss by decay	
		Partially delignified (%)#	Not treated (%)##
1	5.34	19.44	0.68
2	11.72	35.17	0.51
3	3.63	12.56	1.94
4	6.44	16.83	0.00
5	7.37	23.70	1.10
6	2.10	21.34	0.68
7	4.24	19.16	0.94
8	9.30	33.39	4.37
9	5.17	34.21	0.59
10	8.04	38.09	2.61
11	4.86	22.84	1.46
12	9.94	27.92	2.87
13	11.57	58.18	4.12
14	5.48	41.38	10.95
15	8.06	43.04	2.83
16	10.08	38.66	0.82
17	21.92	27.24	10.54
18	4.57	16.39	0.19
19	5.26	30.83	0.00
20	10.38	31.70	1.64
21	5.27	29.84	2.02
22	4.62	23.65	2.27
23	10.32	44.30	7.30
24	4.81	28.24	9.00
25	9.92	56.19	2.37
26	3.38	13.42	1.22
27	13.89	43.29	10.20
28	7.81	48.93	7.34
29	10.13	34.27	7.94
30	4.67	24.21	7.39
31	7.47	28.94	2.41
32	16.82	43.90	0.06
33	13.84	29.10	0.03
34	8.08	25.73	0.21
35	6.04	30.60	4.92
36	6.08	19.86	0.00
37	8.53	25.28	1.24
38	8.37	26.82	1.84
39	1.58	6.24	0.31
40	9.98	49.29	0.87
41	9.62	29.42	1.59
42	18.47	55.04	3.14
43	7.80	31.11	0.00
44	6.18	28.69	0.00
45	10.93	40.27	36.63

* See Table 1.

** $\frac{W_2-W_3}{W_1}\times 100$

$\frac{W_3-W_4}{W_1}\times 100$

$\frac{W_1-W_4}{W_1}\times 100$

W_1: Weight of original wood
W_2: Weight of extracted wood by ethanol-benzene
W_3: Weight of chlorite treated wood
W_4: Weight of decayed wood
(from previous report[10])

preference for wet conditions. The temperature was maintained at 28°C during the 8 week-incubation period. The decayed blocks were cleaned of mycelium, and then dried to constant weight in an oven at 105°C. The percentage loss of weight was calculated from initial and final weights.

Results and Discussion

Table 2 shows the results obtained for the weight losses after the chlorite treatment and the exposure to *Ch. globosum*. The weight losses after the chlorite treatment considerably varied with species. The lowest weight loss was 1.58 % for *Chamaecyparis obtusa* (No. 39) and the highest was 21.92 % for *Larix gmelini* (No. 17). An average value for 44 softwoods was about 8 %. The resistance of softwoods to acidified sodium chlorite was classified into four classes:

I ; weight loss was less than 4 % for 4 species.

II ; weight loss was 4~8 % for 19 species.

III; weight loss was 8~12 % for 16 species.

IV; weight loss was over 12 % for 5 species.

Fagus crenata, only one harwood used in the experiment, could be classified into III.

In the present chlorite treatment of the samples, neither adjustment of pH of the solutions nor addition of chemicals was carried out. Therefore, it was not

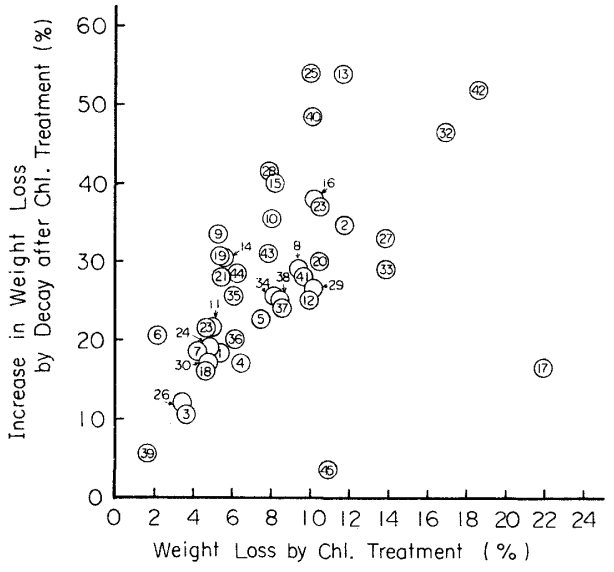

Fig. 1. Acceleration of wood-attacking capacity of *Ch. globosum* on 44 softwood timber species after partial chlorite delignification for 6 hours at 40°C. The points can be identified by the numbers given in Table 1.

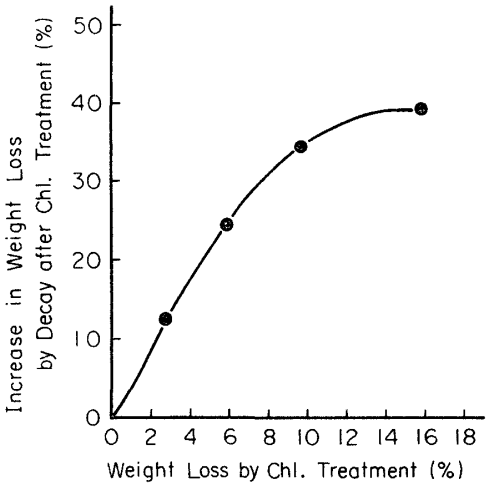

Fig. 2. Summarized data for the acceleration of wood-attacking capacity of *Ch. globosum* on softwoods after partial chlorite delignification for 6 hours at 40°C.

clear that different resistance to chemical attack observed here implies different accessibility of lignin and polysaccharides through the cell wall of softwoods, or different rate of reaction in which several factors, such as pH, temperature and charge of chemicals in an acidified chlorite solution, are concerned. However, noteworthy is the close relation between the weight losses by the treatment and those by decay. Fig. 1 shows the acceleration of decay which is given by the difference in weight losses between treated and untreated samples, as shown in Table 2. The highest acceleration was 54.06 % for *Picea glehnii* (No. 13) and the lowest was 5.93 % for *Chamaecyparis obtusa* (No. 39). *Larix gmelini* (No. 17) exceptionally showed lower acceleration in spite of the lowest resistance to chemical attack. *Fagus crenata* (No. 45) was the same to *Larix gmelini* in respect of its lower acceleration. Both woods, as shown in Table 2 and previous report[10], have relatively lower natural decay resistance. In the case of such species, removal or modification of lignin may be less effective for *Ch. globosum.*

Fig. 2 shows the summarized data for the acceleration of wood decay by *Ch. globosum* after partial delignification. Points on Fig. 2 show average values for four classes of resistance to chemical attack described above. *Fagus crenata* was excluded from the calculation. Acceleration was nearly straight within the range of weight loss by chlorite treatment from 0 to about 10 %, and may possibly reach a maximum level at about 16 % or more.

Fig. 3, 4 and 5 show the results for the acid-soluble lignin of wood shavings from three species of wood (Nos. 19, 36 and 45), treated with acidified sodium chlorite, at various Klason lignin contents. Point, shown as "not treated" on each figure, is an average of data from three separate Klason hydrolysates. There are several indications that the amount of acid-soluble lignin from untreated softwoods is very small[5,6,8]. In agreement with these, the acid-soluble lignin was only 0.26 % for *Pinus densiflora* and 0.37 % for *Cryptomeria japonica. Fagus crenata* showed relatively higher content (2.14 %). This value was lower than that of American beech (4.5 %) obtained by MUSHA and GORING[9] but lay within the range from 1 to 4 %, as reported by SHÖNING and JOHANSSON[8] for hardwoods and straws.

A high level of the soluble lignin during the chlorite process was observed in agreement with several reports[6,11,12]. The maximum was reached at about 9 % of Klason lignin content for *P. densiflora,* at about 14 % for *C. japonica,* and at about 10 % for *F. crenata.*

According to BROWNING[5], who pointed out that a considerable portion of the total lignin is soluble after the acid treatment and the amount of insoluble residue is not a realistic measure of lignin content, the total lignin content was determined as insoluble Klason lignin plus the ultraviolet-estimated acid-soluble lignin.

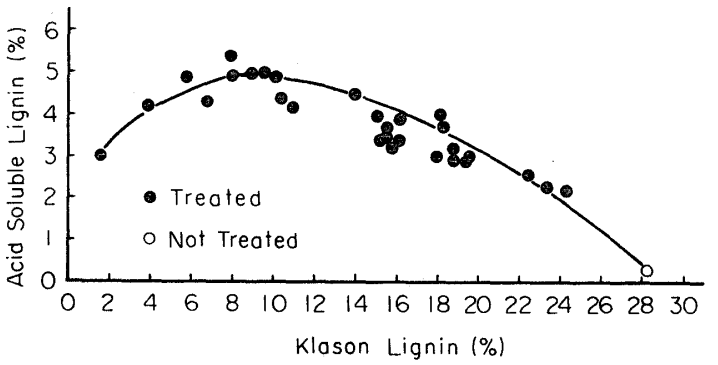

Fig. 3. The amount of acid-soluble lignin from chlorite treated wood of *Pinus densiflora* at different stages of delignification.

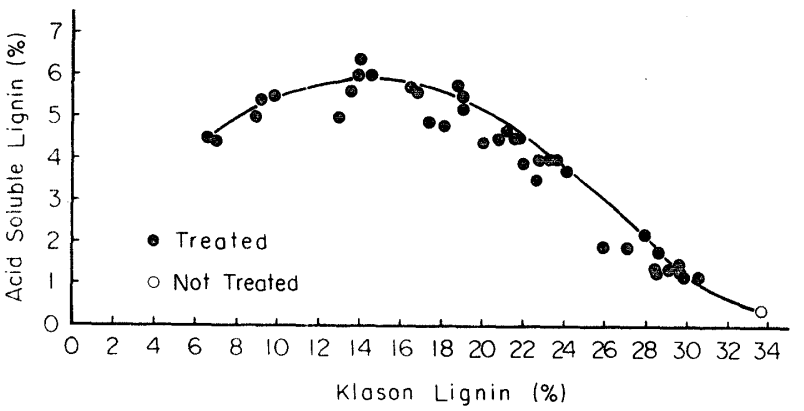

Fig. 4. The amount of acid-soluble lignin from chlorite treated wood of *Cryptomeria japonica* at different stages of delignification.

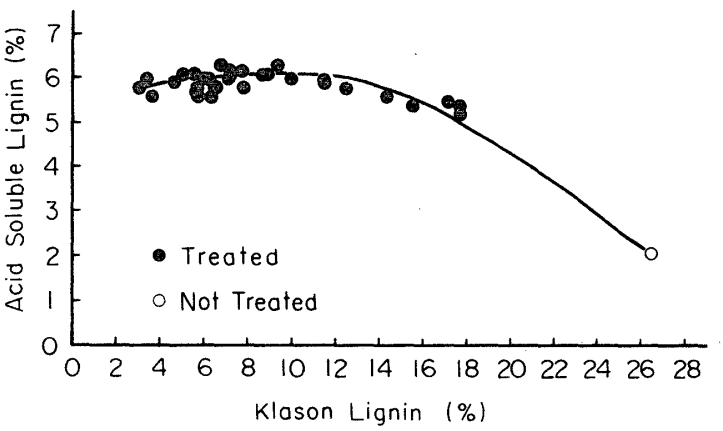

Fig. 5. The amount of acid-soluble lignin from chlorite treated wood of *Fagus crenata* at different stages of delignification.

The pattern of lignin removal from the three species of wood during the chlorite treatment has been shown in Figs. 6, 7 and 8. Difference between the losses in Klason and total lignins is evident for each species. For the purpose of facilitating

discussion, smoothed values from the curves in Figs. 6, 7 and 8 are compiled in Table 3. In addition, the estimated lignin losses are shown in this table, which were calculated on the assumption that the chlorite procedure is selective in removing lignin only. In the case of *C. japonica,* the smoothed values nearly agreed with the estimated values throughout the process. On the other hand, in the case of *P. densiflora* and *F. crenata,* the two values did not agree during the whole stage. Such a disagreement was larger in the case of the latter. In both woods, considering from the material balances, some substances other than lignin should be removed during the process. AHLGREN and GORING[12], based on the results with lignin-

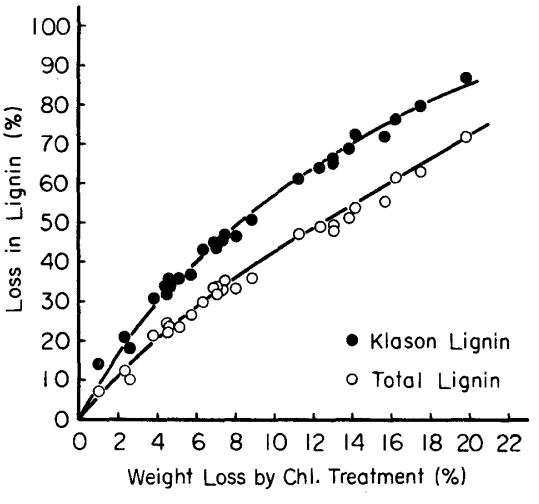

Fig. 6. Decrease of lignin in *Pinus densiflora* during chlorite treatment.

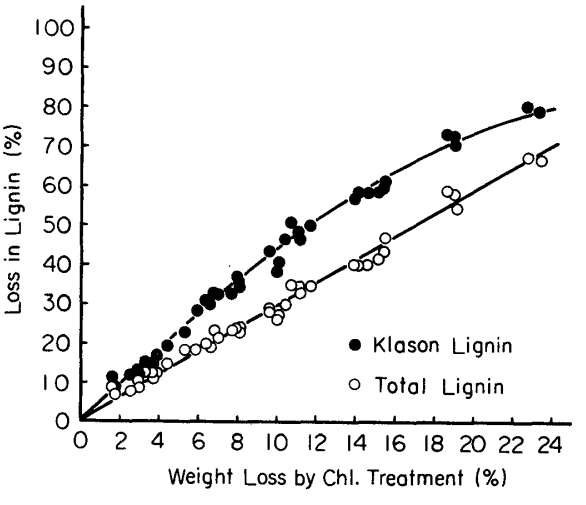

Fig. 7. Decrease of lignin in *Cryptomeria japonica* during chlorite treatment.

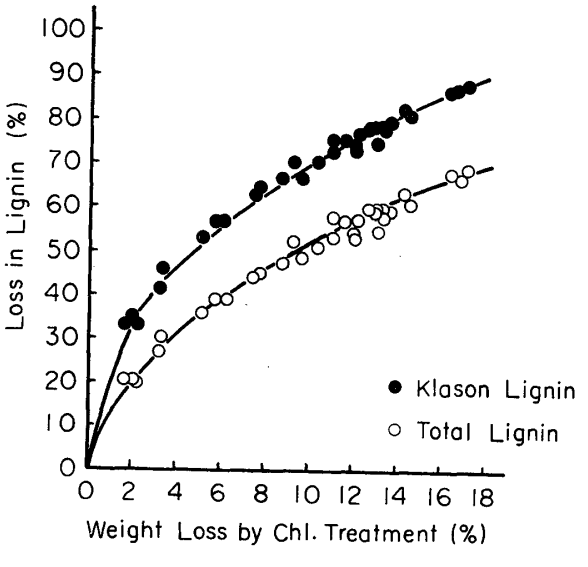

Fig. 8. Decrease of lignin in *Fagus crenata* during chlorite treatment.

and carbohydrate determinations, concluded that the chlorite process is selective in removing lignin from black spruce during the first 60 % of delignification and at later stages of delignification some glucomannan is dissolved. The present work has also shown that the chlorite process is selective in removing lignin only from *C. japonica*. However, it can be considered that the process is less selective in the case of *P. densiflora* and *F. crenata*.

Table 3. The losses in total lignin content at different stages of chlorite treatment.

Weight loss in wood (%)*	Loss in total lignin (%)					
	Smoothed			Estimated		
	PD	CJ	FC	PD	CJ	FC
0	0	0	0	0	0	0
2	11	7	20	7	6	7
4	20	12	31	14	12	14
6	29	18	39	21	18	21
8	36	24	46	28	23	28
10	43	30	53	35	29	35
12	49	35	57	42	35	42
14	55	41	62	49	41	49
16	60	47	66	56	47	66
18	67	53	70	63	53	63
20	72	59	—	70	59	70
22	—	65	—	77	65	77

PD=*Pinus densiflora*
CJ=*Cryptomeria japonica*
FC=*Fagus crenata*
* $\frac{W_2-W_3}{W_2}\times 100$
W_2 and W_3 are same as those in Table 2.

The results with the weight losses in chlorite treated wood after exposure to fungal attack are shown in Figs. 9 to 14. In the case of *F. crenata*, as shown in Figs. 9 and 10, acceleration of decay was poor during first to middle stages of delignification. In the wood, originally susceptible to fungal attack, removal or modification of lignin may be less effective. However, the higher acceleration during middle to later stages is incomprehensible, and further studies should be made on this respect. With respect to the two softwoods, smoothed values from curves in Figs. 11 to 14 are compiled in Table 4.

In the case of *P. densiflora*, the acceleration curve for *Ch. globosum* was steep and reached the maximum at 10 % of weight loss, which was equivalent to 43 % of delignification on the assumption that effect of particle size is negligible in the

chlorite delignification, whereas the curve for *Co. versicolor* was gentle but reached the maximum at greater stage of delignification.

In the case of *C. japonica,* the acceleration pattern was nearly reverse for the two fungi. At the first 2 % of weight loss, equivalent to 7 % of delignification, acceleration of decay was 20 % for *Co. versicolor* but only 3 % for *Ch. globosum.* However, the curve for *Co. versicolor* was reached the maximum level at only 6 % of weight loss (18 % of delignification), whereas the curve for *Ch. globosum* was still

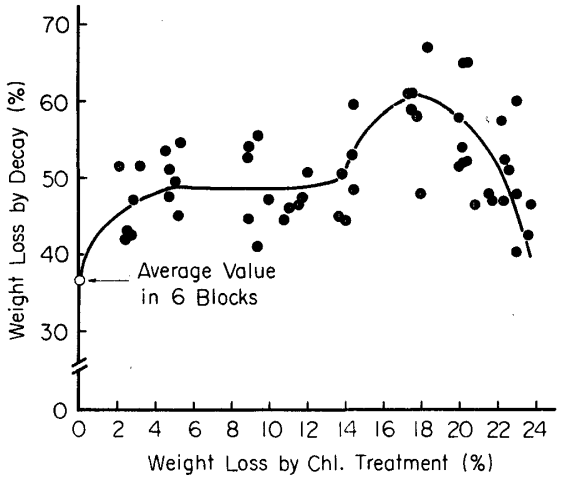

Fig. 9. Weight loss in wood of *Fagus crenata* exposed to *Ch. globosum* for 8 weeks after different degrees of delignification.

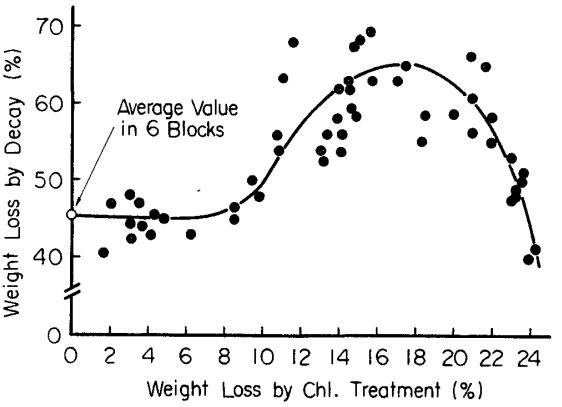

Fig. 10. Weight loss in wood of *Fagus crenata* exposed to *Co. versicolor* for 8 weeks after different degrees of delignification.

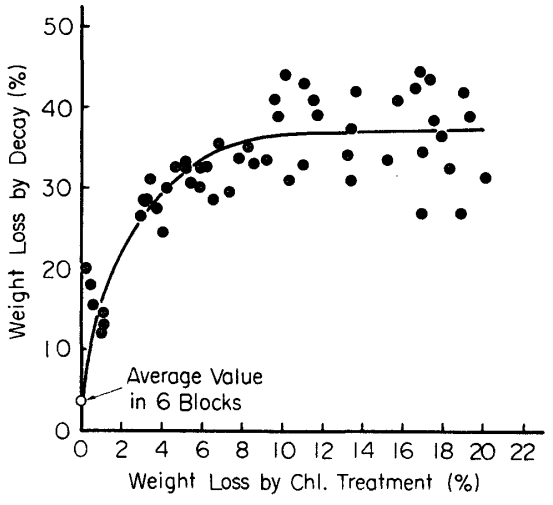

Fig. 11. Weight loss in wood of *Pinus densiflora* exposed to *Ch. globosum* for 8 weeks after different degrees of delignification.

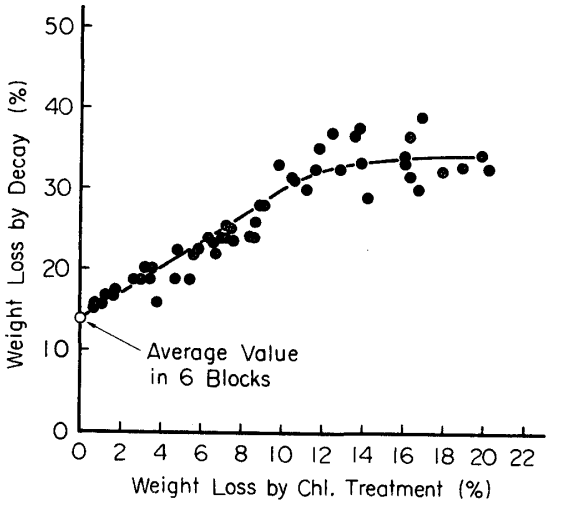

Fig. 12. Weight loss in wood of *Pinus densiflora* exposed to *Co. versicolor* for 8 weeks after different degrees of delignification.

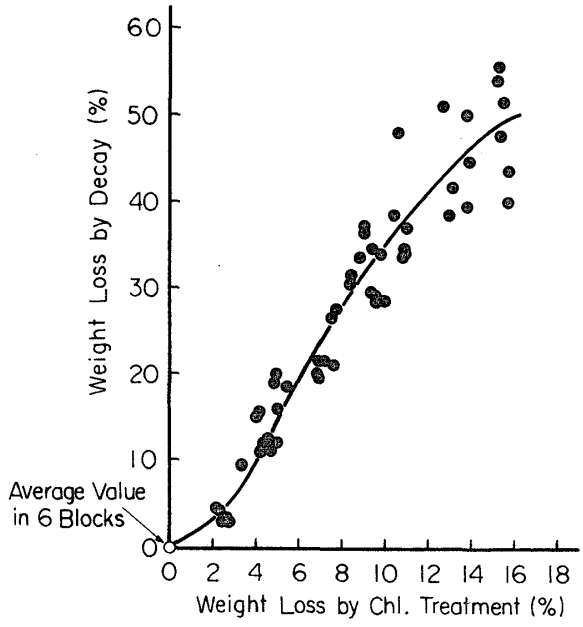

Fig. 13. Weight loss in wood of *Cryptomeria japonica* exposed to *Ch. globosum* for 8 weeks after different degrees of delignification.

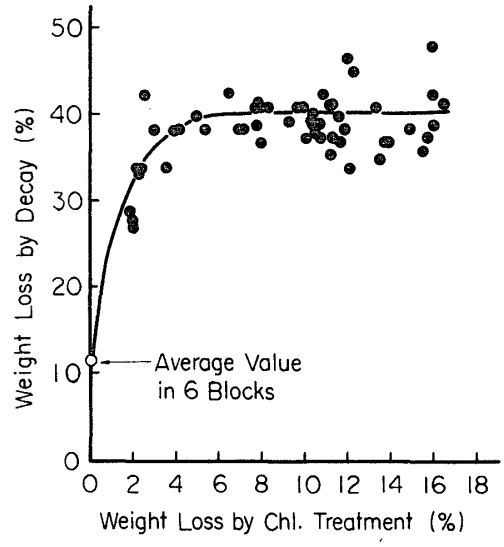

Fig. 14. Weight loss in wood of *Cryptomeria japonica* exposed to *Co. versicolor* for 8 weeks after different degrees of delignification.

Table 4. The acceleration of weight losses at different stages of chlorite treatment.

Weight loss in wood by treatment (%)*	Acceleration of weight loss (%)**			
	CG		CV	
	PD	CJ	PD	CJ
0	0	0	0	0
2	18	3	3	20
4	25	10	6	25
6	30	19	10	27
8	32	28	14	27
10	33	35	17	27
12	33	41	19	27
14	33	46	20	27
16	33	50	21	27

CG = *Chaetomium globosum*
CV = *Coriolus versicolor*
PD = *Pinus densiflora*
CJ = *Cryptomeria japonica*
* $\frac{W_2-W_3}{W_2}\times 100$
** $\frac{W_2-W_3}{W_2}\times 100$ − average weight loss for extracted wood
W_2, W_3 and W_4 are same as those in Table 2.

considerably steep at over 40 % of delignification. Maximum levels in both woods for *Ch. globosum* were higher than those for *Co. versicolor,* in spite of lower attacking capacity of the former on original woods.

BAILEY *et al.*[1] concluded that chlorite treatment of softwoods (*Picea abies* and *Pinus sylvestris*) was less effective for brown rot fungi used (*Coniophora cerebella, Poria vaporaria,* and *Polyporus schweinitzii*). DUNCAN[13] found that leaching in distilled water containing 2 ppm of available chlorine or 0.2 % of sodium carbonate increased the attack of redwood by a white rot fungus, *Poria nigrescens.* From the results obtained in the present work, we may conclude that the chlorite treatment of the two softwoods is effective for both white rot- and soft rot fungi.

Although white rot fungi are regarded as lignin-degrading fungi, they have a preference for hardwoods containing smaller amount of lignin than softwoods. It can be assumed that white rot fungi have two types of enzyme system. The first is involved in breakdown of polysaccharides, and the second is in the breakdown of lignin. Brown rot- and soft rot fungi have certainly the first system only. White rot fungi are thought to be an advanced group, evolved out of a primitive group which is lacking in extracellular oxidase and prefers softwoods to hardwoods[14]. If the second system, associated with lignin degradation, is developed gradually in the course of evolution, this system may possibly be still minor compared with the first system for survival of white rot fungi in the natural habitat. FUKUDA and HARAGUCHI[15] presented that the lignin-degrading capacity of *Coriolus versicolor* might facilitate to utilize cellulose in lignified cell wall but not serve effectively to metabolize lignin itself as energy- and nutrient sources.

Although acceleration of attacking capacity on softwoods by delignification was observed in both soft rot- and white rot fungi, it is difficult to regard the significance of the higher lignin content in softwoods to be the same for both fungi. Moreover, we could not obtain the data for an explanation of acceleration pattern varying with the wood and fungal species. However, at this stage, it can be considered that in the rapid and shorter acceleration of fungal attack a modification of lignin may play an important role, and that a removal of lignin may act as a main agent in the slow and longer acceleration. With respect to this consideration, it will be necessary to deal with the qualitative analyses of substances remaining in the wood after the chlorite process.

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