ASH, SILICA, AND LIGNIN IN NEW ZEALAND BEECH

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ABSTRACT

The ash, silica, and lignin content were determined for beech (**Nothofagus** spp.) and other hardwood species (**Quintinia acutifolia**, **Metrosideros robusta**, **Weinmannia racemosa**) of the South Island beech forests. Wood samples from all species had moderately high ash content (about 0.6 percent). Bark from the four beech species had extremely high ash contents of 3-7 percent.

Wood from all 15 mountain beech and one of the hard beech trees examined contained significant but only moderately large amounts of silica. All other wood samples were essentially free of silica.

Acid-soluble lignin constituted about 20 percent of the total lignin and about 4 percent of the wood substance in all wood samples examined.

INTRODUCTION

The results of a recent study of the ash, silica, and lignin contents of beech and other hardwood species in the West Coast and Southland beech forests are discussed in this paper. The South Island beech forests have assumed major importance because of current proposals for their utilisation in production of timber, pulp, paper, and board (New Zealand Forest Service, 1974). The forests contain four species of beech—silver beech (*Nothofagus menziesii* (Hook f.) Oerst.), red beech (*Nothofagus fusca* (Hook f.) Oerst), mountain beech (*N. solandri* var. *cliffortiodes* (Hook f.) Poole), and hard beech (*N. truncata* (Col.) Cokn.)—and three other hardwood species of interest—quintinia (*Quintinia acutifolia* Kirk), rata (*Metrosideros robusta* A. Cunn.) and kamahi (*Weinmannia racemosa* Linn. f.).

Ash is important because wood with a high ash content may cause problems in the recovery operations of a chemical pulp mill and may also affect the quality of dissolving pulp that can be produced. The production of dissolving pulp, which is used in the manufacture of regenerated cellulose products such as rayon, is currently being examined at the Forest Research Institute as a possible way of utilising the South Island beech forest resource. Our interest in ash and silica was prompted by the fact that dissolving pulps must be virtually free of these components (Brasch *et al.*, 1962; Kerr, 1975). Silica in wood also causes problems in sawmilling operations (Farmer, 1967; Orman and Harris, 1974; Uprichard, 1974) and it may be the reason for difficulties experienced in the sawing of mountain and hard beech in the South Island (Reid, 1947; Orman and Harris, 1974).

Acid-soluble lignin is known to constitute a significant proportion of the total

lignin in most hardwoods (Kerr, 1974; Musha and Goring, 1974) and recent studies (Kerr, unpublished data) have shown that its rate of removal during kraft pulping is similar to that of Klason lignin. However, the acid-soluble lignin contents of the hardwood species in the South Island forests have not been measured previously.

EXPERIMENTAL

Representative chip samples were obtained from the wood of between three and five trees of each of the four beech species. A sample of the bark of each species was also obtained from these trees. Representative chip samples of quintinia, rata, and kamahi were taken from the wood of five trees of each species. The trees were supplied by the New Zealand Forest Service from the Inangahua A site on the West Coast. Discs from 10 Southland mountain beech trees were also supplied and sectors from the discs were cut into small chips.

All chip and bark samples were ground in a Wiley mill to produce 40-mesh sawdust. The untreated sawdust samples were analysed for ash content by the Tappi standard method T211 m-58. The resultant ash samples were analysed for silica by the US Forest Products Laboratory method (Moore and Johnson, 1967), by treating the ash with hydrofluoric acid and measuring the loss of silica as volatile silicon tetrafluoride.

Samples of the remaining sawdust were extracted with methanol (Uprichard, 1962) and the Klason or acid-insoluble lignin contents were determined by the Tappi standard method T13 m-54. Acid-soluble lignin was determined from the UV absorbances of the Klason hydrolysates at 205 nm, using an absorptivity of 113.4 litres/g/cm (Schöning and Johansson, 1965; Swan, 1965). All the above analyses were done in duplicate.

RESULTS AND DISCUSSION

The ash and silica contents of the West Coast samples are given in Table 1. It is apparent that the wood of all species contained appreciable amounts of ash. Mountain beech samples generally contained more total ash than the other samples, although the non-silica ash contents were similar. The non-silica ash ranged from 0.3 to 1.0% for all samples, with a mean of about 0.6%. Hardwoods commonly contain 0.4-0.8% ash, while softwoods like New Zealand *Pinus radiata* generally contain less than 0.3% (Rydholm, 1965). The beech bark samples all had extremely high ash contents (3-7%). This may be a factor against the use of beech whole-tree chips in pulping operations.

Silver beech, red beech, quintinia, rata, and kamahi wood samples did not contain significant amounts of silica. However, all mountain beech samples contained silica; 20-40% of the total ash and 0.1-0.5% of the wood substance. While significant, these silica contents are much lower than those of 1-2% reported for many other woods (Farmer, 1967). One of the hard beech samples contained a significant amount of silica while the other two did not. Similar variable results have been obtained earlier for hard beech (Orman and Harris, 1974; Uprichard, 1974). A possible explanation is that hard beech is known to hybridise with mountain beech (Poole, 1951) and the samples containing silica may well have come from hybrids.

Mountain beech trees nearly always contain significant quantities of silica; further

TABLE 1—Ash and silica contents of the West Coast species

Species	Sample No.	Ash content	Silica in ash	Silica in wood
Silver beech	S1	0.32	0.9	0.00
	S2	0.38	1.8	0.01
	S3	0.90	0.5	0.00
Red beech	R1	0.50	3.2	0.02
	R2	0.60	1.3	0.01
	R3	0.41	1.3	0.01
	R4	0.55	3.8	0.02
Mountain beech	M1	1.37	30.8	0.42
	M2	1.23	39.4	0.49
	M3	0.81	22.2	0.18
	M4	0.61	21.8	0.13
	M5	0.92	32.0	0.29
Hard beech	H1	0.58	6.1	0.04
	H2	0.51	6.1	0.03
	H3	0.51	50.3	0.26
Quintinia	Q	0.73	4.5	0.03
Rata	R	0.60	2.1	0.01
Kamahi	K	0.61	2.4	0.01
Silver beech (bark)	SB	5.45	2.8	0.15
Red beech (bark)	RB	3.05	6.5	0.20
Mountain beech (bark)	MB	6.62	8.1	0.53
Hard beech (bark)	HB	4.97	4.2	0.21

Values given as percentage of o.d. wood, bark or ash. Wood and bark analyses are means of 2 determinations agreeing within 0.02%.

results for 10 Southland mountain beech trees are given in Table 2. The silica contents were 10-60% of the total ash and 0.1-0.7% of the wood substance. The non-silica ash averaged about 0.6%, similar to the average for all the West Coast hardwood samples. The heartwood of tree SM7 had a higher ash content than the sapwood but the silica contents (in terms of o.d. wood substance) were very similar. Silica in mountain beech is known to be contained in the ray cells (Reid, 1947; Orman and Harris, 1974).

The Klason and acid-soluble lignin contents of the West Coast samples are given in Table 3. The values are means of at least two determinations agreeing within 0.6% for Klason lignin and 0.2% for acid-soluble lignin in most cases. Heights and diameters of the individual beech trees, basic densities (i.e., ratios of the weight of o.d. wood to its green volume) of the chip samples, and methanol extractives contents are also given. The Klason lignin contents are given as percentages of the original unextracted wood. The values are consistently higher than those measured previously on samples

TABLE 2—Ash and silica contents (as percentage of o.d. wood or ash) of Southland mountain beech specimens

Sample No.	Age of tree (yrs)	Ash content	Silica in ash	Silica in wood
SM1	114	0.63	18.2	0.11
SM2	98	1.08	19.6	0.21
SM3	106	0.65	36.7	0.24
SM4	104	0.53	39.2	0.21
SM5	132	0.86	30.7	0.26
SM6	93	0.43	6.1	0.03
SM7 (sap)	140	0.68	31.9	0.22
SM7 (heart)	140	1.12	18.1	0.20
SM8	150	0.62	10.5	0.07
SM9	75	0.69	11.4	0.08
SM10	88	1.19	57.4	0.68

TABLE 3—Tree sample data and wood basic density; together with methanol extractives, and Klason, acid-soluble and total lignin contents (as percentage of original o.d. wood)

Sample No.	Diameter at breast height (mm)	Merchantable height (m)	Basic density (kg/m^3)	Methonal extractives	Klason lignin	Acid-soluble lignin	Total lignin
S1	589	19.5	453	1.7	23.2	4.8	28.0
S2	386	16.8	411	2.5	24.7	4.5	29.2
S3	264	14.3	437	5.5	23.0	4.7	27.7
R1	653	24.7	536	10.4	19.0	3.7	22.7
R2	378	17.1	473	9.5	21.0	3.6	24.6
R3	279	13.4	477	6.4	19.0	3.9	22.9
R4	170	9.8	460	2.9	20.4	4.2	24.6
M1	391	12.8	530	4.7	21.6	3.8	25.4
M2	328	14.0	508	4.9	18.3	4.0	22.3
M3	287	15.9	489	3.4	18.0	3.6	21.6
M4	196	10.4	504	3.1	21.4	3.7	25.1
M5	158	9.8	517	3.8	18.0	4.0	22.0
H1	589	19.5	516	3.8	19.3	4.0	23.3
H2	427	18.9	567	8.0	17.5	3.9	21.4
H3	297	13.4	531	6.2	17.5	4.4	21.9
Q	—	—	484	3.6	23.0	3.8	26.8
R	—	—	788	10.9	23.7	3.2	26.9
K	—	—	542	7.6	22.8	3.0	25.8
SB	—	—	—	7.5	43.5	1.9	45.4
RB	—	—	—	19.7	26.6	3.3	29.9
MB	—	—	—	14.6	36.0	3.0	39.0
HB	—	—	—	18.8	25.0	3.2	28.2

of the same species obtained from other areas of the South Island (Uprichard, 1964; Harwood, 1972; 1973). As found previously, silver beech had a higher and hard beech a lower Klason lignin content than the other beech species. The values for quintinia, rata, and kamahi were similar to those for silver beech. The bark samples, particularly those from silver and mountain beech, had fairly high contents of material measured as "Klason lignin". With bark, non-lignin material such as high molecular weight polyphenolic compounds could well be included in the Klason residue.

Acid-soluble lignin constituted a significant proportion (generally about 20%) of the total lignin in all wood samples examined as had been the case with other hardwoods (Musha and Goring, 1974). Silver beech contained slightly more acid-soluble lignin than the other species. However, the variation both within and between species was small, and the mean and 95% confidence limits for all samples were $3.9 \pm 0.2\%$. The beech bark samples had slightly lower acid-soluble lignin contents than the corresponding wood samples.

CONCLUSIONS

1. Wood from all main hardwood species in the South Island beech forests had moderately high ash contents (about 0.6%) which could possibly cause problems in future pulping operations.
2. Mountain beech wood samples from the West Coast and Southland forests contained moderately high amounts of silica (0.03-0.68%). With the exception of one of the hard beech trees, wood samples from all other species were essentially free of silica.
3. All wood samples contained about 4% of acid-soluble lignin and this generally amounted to about 20% of the total lignin. Because acid-soluble lignin is important in chemical pulping, the lignin contents of such hardwoods should always be expressed as the sum of Klason and acid-soluble lignin.
4. Bark from the four beech species had extremely high ash contents of between 3 and 7%, and also contained large amounts of total "lignin" and methanol extractives, the three components totalling between 50 and 60% of the bark substance. For this reason the pulping of whole-tree chips containing bark is unlikely to prove desirable.

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REFERENCES

BRASCH, D. J., FREE, K. W., TUCKER, D. H. and VINCENT, T. A. 1962: The preparation of rayon grade pulps from **Pinus radiata**. In "Rayon Pulp Production in New Zealand" (10th New Zealand Science Congress) N.Z. DSIR, Dominion Laboratory, Wellington.

FARMER, R. H. 1967: "Chemistry in the Utilisation of Wood". Pergamon Press, Oxford. p.63.

HARWOOD, V. D. 1972: The chemistry of **Nothofagus fusca**. I. Characteristics of xylan and alpha-cellulose in relation to extraction techniques. **N.Z. For. Serv., For. Res. Inst., For. Prod. Rep. 373** (unpubl.).

——— 1973: The chemistry of **Nothofagus** spp. II. Xylans from heartwood and sapwood of the four major species. **N.Z. For. Serv., For. Res. Inst., For. Prod. Rep. 445** (unpubl.).

KERR, A. J. 1974: Physicochemical mechanisms of delignification. Ph.D. Thesis, McGill University.

——— 1975: New pulping processes. 2. Nitric acid. **N.Z. For. Serv., For. Res. Inst., Pulp and Paper Rep. 9** (unpubl.).

MOORE, W. E. and JOHNSON, D. B. 1967: Procedures for the chemical analysis of wood and wood products. **US For. Prod. Lab. Handbook.**

MUSHA, Y. and GORING, D. A. I. 1974: Klason and acid-soluble lignin content of hardwoods. **Wood Sci. 7 (2):** 133-4.

NEW ZEALAND FOREST SERVICE 1974: "Invitations for proposals to Use Wood from Beech Forests, West Coast and Southland, South Island, New Zealand". Government Printer, Wellington. 24pp.

ORMAN, H. R. and HARRIS, J. M. 1974: The utilisation of beech timbers—properties of beech timbers. **In** "Beech Forestry in New Zealand, Vol. II". **N.Z. For. Serv., For. Res. Inst., Symposium 5.** pp. 9-14.

POOLE, A. L. 1951: Hybrid southern beeches. **N.Z.J. For. 6:** 250-3.

REID, J. S. 1947: Silica in beech timbers. **N.Z.J. For. 4:** 330-1.

RYDHOLM, S. A. 1965: "Pulping Processes". Interscience, New York p. 93.

SCHONING, A. G. and JOHANSSON, G. 1965: Absorptiometric determination of acid-soluble lignin in semichemical bisulfite pulps and in some woods and plants. **Svensk PappTidn. 68:** 607-13.

SWAN, B. 1965: Isolation of acid-soluble lignin from the Klason lignin determination. **Svensk PappTidn. 68:** 791-5.

UPRICHARD, J. M. 1962: Quantitative determination of extractives in woods. **N.Z. For. Serv., For. Res. Inst., For. Prod. Rep. 103** (unpubl.).

——— 1964: Pulping qualities of silver beech (**N. menziesii**). **N.Z. For. Serv., For. Res. Inst., For. Prod. Rep. 136** (unpubl.).

——— 1974: The prospects of utilising beeches for pulp. **In** "Beech Forestry in New Zealand Vol. II". **N.Z. For. Serv., For. Res. Inst. Symposium 5.** Pp. 51-7.