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EFFECTS OF TREE AGE ON KRAFT PULPING OF *PINUS RADIATA*

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The findings of various N.Z. Forest Products Limited laboratory studies on the effects of tree age on kraft pulping of **P. radiata** are described. The most important effect of increasing tree age is to increase the basic density of the wood. Results showed that kraft pulping characteristics and pulping properties are closely related to and can be predicted from pulpwood basic density.

In this paper the emphasis is placed on comparing the kraft pulping of youngwood (12-, 13-year-old thinnings) with that of the normal pulpwood supply to the Kinleith mill (effective tree age of about 30 years). The youngwood chips showed a lower packing density, but pulped at a faster rate and produced a higher yield of pulp at a given Kappa.

Calculations which took these 3 factors into account showed that the production capacity of a pulping digester would be more than 10% lower when utilising the youngwood in place of normal Kinleith pulpwood.

Youngwood pulps were easier to beat to a given handsheet bulk or bonding strength property (burst or breaking length), but had much lower tear strengths than pulps from older wood. The tear index at 6.0 burst index for pulp from youngwood thinnings was about 25% lower than that of pulp from normal Kinleith pulpwood.

The availability of the kraft pulping by-product, crude tall oil, was found to be significantly lower for youngwood and the tall oil contained a lower proportion of resin acids.

INTRODUCTION

The effects of tree age on wood properties and thus on kraft pulping characteristics and pulp properties are reviewed in this paper. The paper which was presented at the FRI Symposium No. 23 is based on studies made in the laboratories of N.Z. Forest Products Limited (NZFP) during the period 1966–1980.

The effects of tree age on the kraft pulping of *P. radiata* is of considerable practical concern to the Company because over the past few years, there has been a decrease in the effective age of pulpwood supplied to the Kinleith mill. This has led to some segregation of pulpwood supplies and has provided an opportunity to tailor-make pulps, particularly from youngwood, for use in specific paper qualities.

In this paper, the kraft pulping of youngwood thinnings (12-, 13-year-old trees) and the normal average pulpwood supply to the Kinleith mill, are compared and the

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effects of tree age are assessed. The data have been extracted from NZFP internal reports and the contributors to the data base together with the study periods, are listed in the Acknowledgments.

MATERIALS AND METHODS

All the laboratory kraft pulps were produced from screened chips (+12 mm to —28 mm accept fraction) and were cooked using the following range of conditions:

% active alkali	16–18
% sulphidity	23–25
liquor to wood ratio	3.5 : 1–4.0 : 1
top temperature	170–185°C
H-factor	1500–2000

RESULTS AND DISCUSSION

Effects on wood properties

The major effect of tree age on kraft pulping arises from its effect on basic density. It will be shown later that all pulping characteristics and pulp properties are closely related to pulpwood basic density. Data from a number of studies are plotted in Fig. 1. Despite considerable scatter there is a clear relationship between tree age and whole-log basic density.

Thinnings supplied to the Kinleith mill are normally 13 and 20 years old. Much of the wood from these thinnings is now supplied to the Nos. 1–6 batch digesters. The basic density of 13-year-old whole-log thinnings is 350–360 kg/m³ and that of 20-year-old thinnings is 370–380 kg/m³ (Fig. 1). Pulpwood supplied to the No. 2 continuous digester (CD) is, however, a mixture of whole-log, slabwood, tops, and

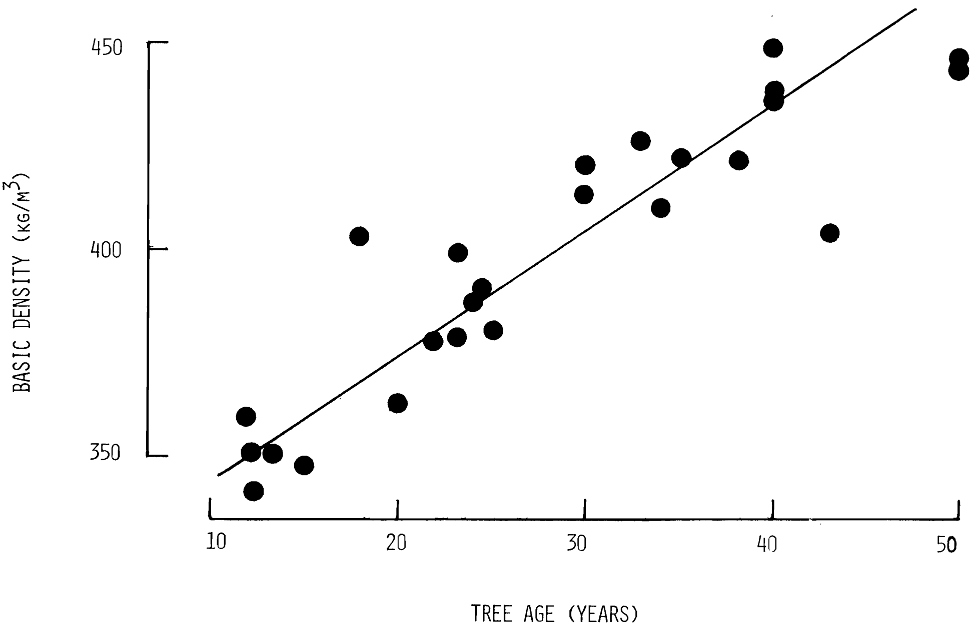


FIG. 1—The increase in whole-log basic density with increasing tree age.

TABLE 1—Decreases in pulpwood basic density at Kinleith

Year	Av. pulpmill basic density (kg/m³) Batch digesters	No. 2 continuous digester
1975	430	436
1976	426	426
1977	412	426
1978	402	413
1979	402	414

thinnings and has an average basic density of 415–420 kg/m^3, corresponding to an effective tree age of 30–35 years.

It is relevant at this stage to look at the decreases in pulpwood basic density that have been experienced at Kinleith in recent years (Table 1).

Because of past patterns of forest planting and utilisation, in 4 years the average pulpwood density has decreased from 433 to 408 kg/m^3. This trend is expected to continue over the next few years and is certainly not limited to NZFP's wood supply. It is evident that any new chemical pulpmill which might be constructed in New Zealand in the 1990s will be utilising a higher proportion of youngwood than has recently been the case.

R. P. McCully and T. Hongladarom conducted a comprehensive laboratory study in which the effects of tree age on wood properties, kraft pulping characteristics, and pulp properties were investigated. These workers studied 13-, 23-, 40- and 50-year-old trees, the 40- and 50-year-olds being subdivided into top and butt logs. Chips were produced on the appropriate Kinleith mill chipper. The results for wood properties are given in Table 2. These show clearly that basic density, oven dry (o.d.) content, extractives content, and fibre length all increase significantly with increasing tree age. These wood properties all have an important effect on pulping but as shown later, for simplicity pulping parameters can be related to basic density alone.

Kraft pulping characteristics

Results from the study by McCully & Hongladarom are summarised in Table 3. Chip packing density, which provides an indication of the o.d. wood charge that can be packed into a pulping digester, increases substantially with increasing tree age. We

TABLE 2—Effects of tree age on wood properties

Wood properties	Tree age (position) 13	23	40 (Top)	40 (Butt)	50 (Top)	50 (Butt)
No. of trees	25	12	6	6	6	6
Basic density (kg/m³)	351	399	420	454	436	452
O.d. content (%)	36.9	45.2	48.8	51.0	51.0	52.3
Alcohol/benzene extractives (%)	0.97	1.94	2.06	1.91	1.95	2.45
Fibre length (mm)	3.19	3.37	3.48	3.38	3.68	3.63

TABLE 3—Effects of tree age on kraft pulping

Pulping results	Tree age (position)					
	13	23	40 (Top)	40 (Butt)	50 (Top)	50 (Butt)
Chip packing density (kg/m^3)	146	163	170	187	176	189
Pulp Kappa no. (equivalent pulping conditions)	26.6	29.6	29.5	30.5	29.3	31.6
Total pulp yield at Kappa 30 (%)	48.6	47.1	47.0	46.3	45.6	45.8
Screen rejects at Kappa 30 (%)	0.3	0.5	0.3	0.5	0.5	0.8

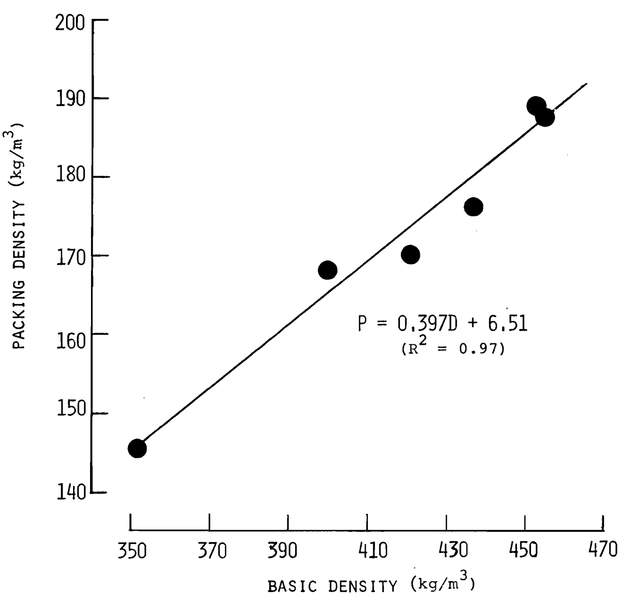
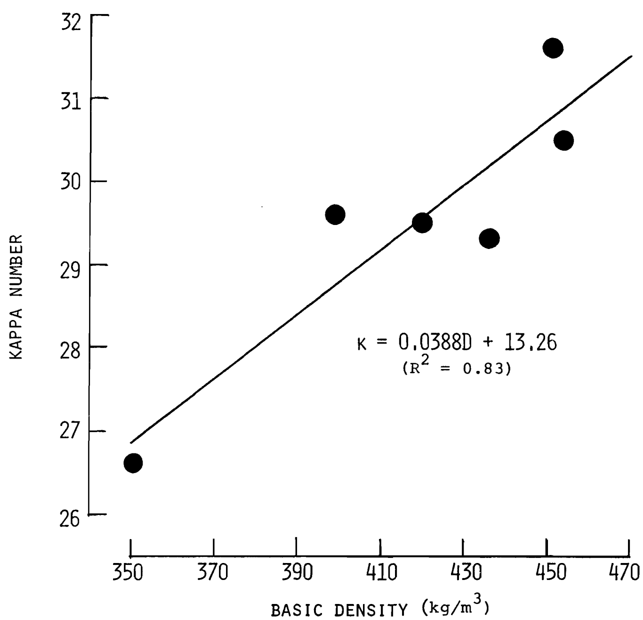


FIG. 2—Linear relationship between packing density and basic density.

have established a good linear relationship between packing density and basic density as shown in Fig. 2.

Both the rate of pulping and pulp yield at Kappa 30 decreased with increasing tree age (Table 3). Again, we established linear relationships between pulp Kappa (indicative of pulping rate) and pulp yield at Kappa 30 with basic density as shown in Figs 3 and 4. In Fig. 4, data from a study by R. N. Jones on youngwood thinnings and data from Kinleith Pulp Quality work (laboratory pulping of monthly composites of Kinleith pulpwood samples), were combined with those of McCully & Hongladarom. The decrease in pulp yield with increasing basic density was unexpected and the general trend may well be different. This relationship may depend on whether the wood source is whole wood, slabwood, tops, etc., and more work is needed to clarify the situation.

FIG. 3—Linear relationship between pulp Kappa number and basic density.



The proportion of screen rejects in kraft pulp also increased with increasing tree age (Table 3). No specific explanation is offered although it is dependent to some extent on chipper operation, chip thickness distribution, percentage of heartwood, morphological knots, etc.

A further aspect of laboratory kraft pulping which we have studied is the effect of tree age on the availability and composition of the kraft pulping by-product, crude tall oil. The data plotted in Figs 5 and 6 show that both tall oil availability from the wood and the relative ratio of resin to fatty acids in the tall oil increased substantially with increasing tree age.

Kraft pulp properties

Results from the study by McCully & Hongladarom are given in Table 4. One of our main difficulties was in deciding how to compare the handsheet results. We chose to compare the data at equivalent beating revolutions and also, in particular for tear strength, at equivalent bonding strength (burst). The youngwood pulps (13-year-olds) were much easier to beat, as evidenced by their lower bulk and burst strength, but had substantially lower tear strength than pulps from the older wood. Tear at 6 burst is also given in Table 4 to show that tear strength was also substantially lower for youngwood pulps when the comparison is made at equivalent handsheet bonding strength.

These findings were substantiated in a study by B. J. Fergus who collected chips from various Kinleith mill chippers which were known to handle particular age classes of wood. The chip samples were kraft pulped in the laboratory and pulp properties were evaluated (Table 5). Pulps from the youngwood thinnings all had lower handsheet bulk, lower tear, and higher burst and breaking length at a given degree of beating than pulps from older whole-logs and from slabwood.

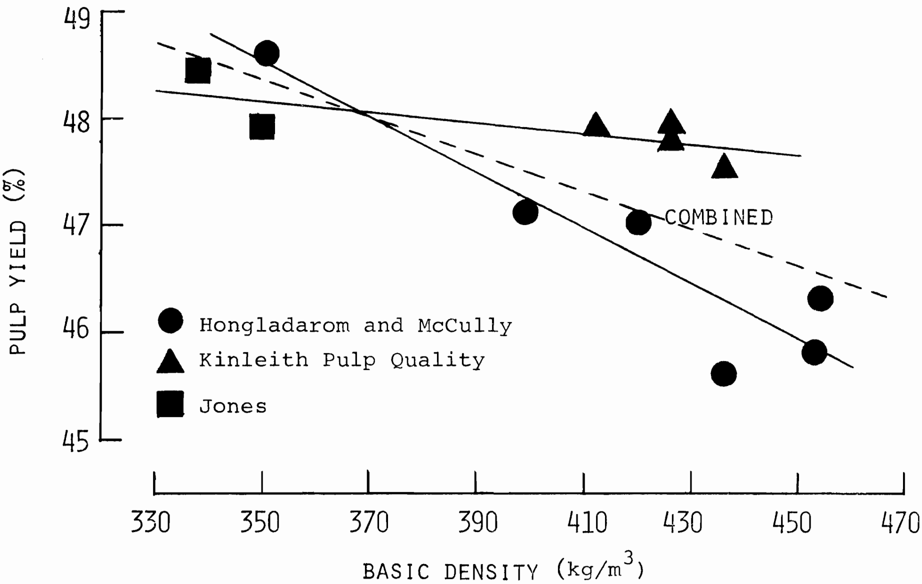


FIG. 4—Linear relationship between pulp yield at Kappa 30 and basic density

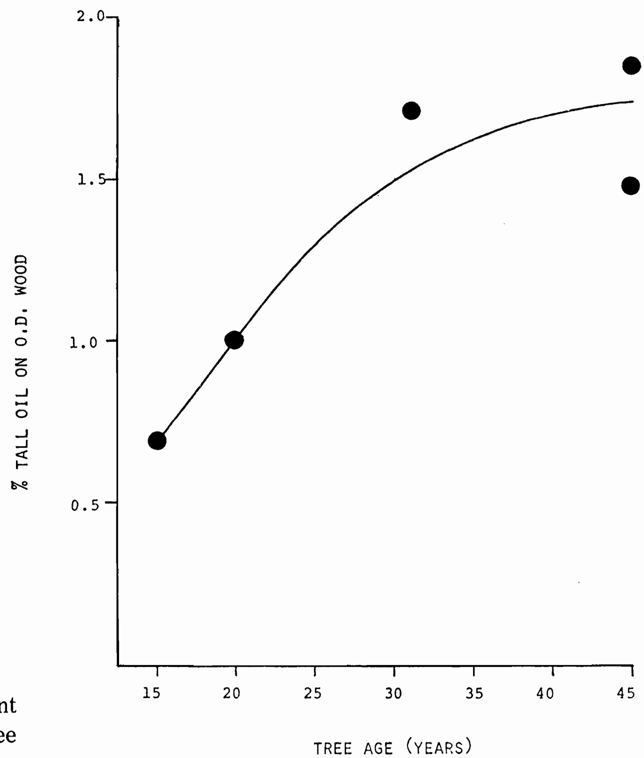


FIG. 5—Tall oil content (whole-tree) **versus** tree age.

FIG. 6—Resin acids in tall oil (%) **versus** tree age.

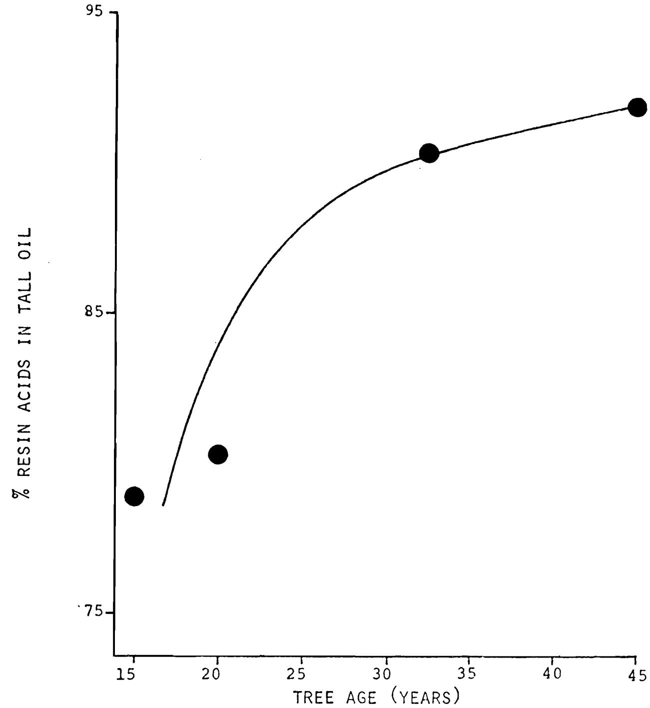


TABLE 4—Effects of tree age on pulp properties

Pulp properties	Tree age (position)					
	13	23	40 (Top)	40 (Butt)	50 (Top)	50 (Butt)
Properties at 3500 rev. Lampen						
Bulk (cm^3/g)	1.49	1.60	1.65	1.68	1.62	1.62
Tear Index	13.3	22.6	21.6	26.6	22.9	20.8
Burst Index	6.0	5.3	5.4	4.9	5.5	5.6
Tear index at 6.0 Burst Index	13.3	19.5	18.6	20.4	20.7	18.9

TABLE 5—Properties of kraft pulp from thinnings and older wood

	Pulp properties at 2000 rev. Lampen				
	Freeness (Csf)	Bulk (cm^3/g)	Tear Index (mNm^2/g)	Burst Index ($kPam^2/g$)	Breaking length (km)
Small diameter thinnings (**c.** 13 years old)	693	1.50	13.4	5.6	7.4
Larger diameter thinnings (**c.** 13 years old)	729	1.48	13.6	5.4	7.3
Larger whole log thinnings (**c.** 20 years old)	706	1.46	14.7	6.0	7.4
Larger whole logs	736	1.55	20.2	5.2	6.8
Mainly slabwood	740	1.62	26.1	4.0	5.9

The study by R. N. Jones was part of a genetic progeny trial in which the properties of a genetically "superior" group of 12-year-old *P. radiata* trees were compared with those of a "control" group. The "superior" trees had shown gains in wood volume of up to 43%. Average whole-log basic densities for the control and superior chips were 338 and 350 kg/m³ respectively. Whole-log chip samples were kraft pulped in the laboratory and pulp yield data were plotted in Fig. 4 which was discussed earlier. Pulp properties are compared in Table 6 with those of the average properties of Kinleith Pulp Quality pulps prepared from No. 2 CD chips (average basic density 426 kg/m³) during 1977.

There were no significant differences between the "control" and "superior" pulps. Comparison of the properties of these youngwood pulps with the Kinleith Pulp Quality properties showed the same trends as found in the earlier studies.

TABLE 6—Properties of kraft pulp from 12-year-old trees

Pulp properties	12-year-old trees: Controls	12-year-old trees: Superior progeny	Mean for Kinleith No. 2 CD Chips 1979
Properties at 2000 rev. PFI			
Freeness (Csf)	674	659	710
Bulk (cm³/g)	1.39	1.37	1.56
Tear Index (mNm²/g)	14.5	13.8	24.0
Burst Index (kPam²/g)	7.3	7.6	5.9
Breaking length (km)	8.7	9.2	7.5
Properies at 6.0 Burst Index			
Beating rev. (×10⁻³)	0.6	0.3	1.8
Freeness (Csf)	707	710	711
Bulk (cm³/g)	1.49	1.50	1.57
Tear Index (mNm²/g)	17.0	16.8	23.6
Breaking length (km)	7.5	6.8	7.4

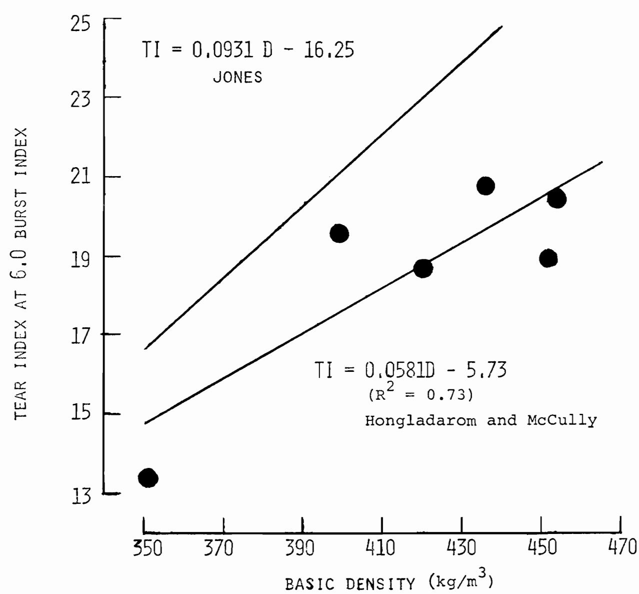


FIG. 7—Tear Index at 6.0 Burst Index **versus** basic density.

Jones prepared a linear regression equation relating tear index at 6.0 burst index to pulpwood basic density for data from the progeny trial study and from Kinleith Pulp Quality work. This equation is plotted in Fig. 7 along with the data of McCully & Hongladarom. Although the tear values from McCully & Hongladarom's study are lower than those from Jones', the regression lines show the same trend and are not too dissimilar.

COMPARISON OF THINNINGS AND KINLEITH PULPWOOD

It is of interest to make a direct comparison of the kraft pulping of 12-, 13-year-old thinnings (basic density 360 kg/m^3) with that of the normal Kinleith No. 2 CD pulpwood supply (basic density of, say, 420 kg/m^3). The previous data relating pulping parameters to basic density were used to estimate the appropriate parameters for these 2 pulpwood supplies (see Table 7).

TABLE 7—Comparison of kraft pulping of thinnings with normal Kinleith pulpwood

Kraft pulping parameters	12-, 13-year-old thinnings	Kinleith No. 2 CD pulpwood
Basic density (kg/m^3)	360	420
Packing density (kg/m^3)	150	175
Pulp Kappa no.	27.3	29.5
Pulp yield at Kappa 30	48.4	47.4
Tear Index at 6.0 Burst Index	17.3	22.9
Tear Index at 350 Csf	12.7	17.3

As expected, the youngwood pulped at a faster rate but, although the pulp yield was higher, much less can be packed into a pulping digester. Equations developed by A. J. Kerr enabled these 3 factors to be taken into account in calculating the relative production capacity for a commercial digester. The calculations showed that the production capacity for the youngwood thinnings was 10.4% lower than for the normal Kinleith pulpwood.

For some paper grades (e.g., sackkraft and packaging papers), youngwood pulp is inferior because of the much lower tear strength (Table 7). However, the easier beating nature and shorter fibre length of the youngwood pulps lead to better conformation of the paper sheet and make these pulps more suitable for end-uses such as writing papers and certain speciality products.

ACKNOWLEDGMENTS

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