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EUCALYPT BREEDING CO-OPERATIVE
(McCONNOCHIE)

MECHANICAL PULPING OF NZ-GROWN EUCALYPTS
PART 1: THE EFFECT OF WOOD TYPE

JOHN D. RICHARDSON

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CONFIDENTIAL

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MECHANICAL PULPING OF NZ-GROWN EUCALYPTS
PART 1: THE EFFECT OF WOOD TYPE

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SUMMARY

The mechanical pulping potential of *E. nitens* (Central Victoria), *E. nitens* (NSW), *E. regnans* and *E. fastigata* has been evaluated. For each wood type, cold soda pulps were produced in the NZ FRI refiner pilot plant by impregnating chips prepared from 15 year-old trees with a 40 g/L sodium hydroxide liquor. The chips were then cooked for 20 minutes at 50^{o}C. For the *E. nitens* (CV), cold soda pulps were also produced from eight year-old trees to enable the influence of wood age on mechanical pulp properties to be assessed.

The 15 year-old *E. nitens* (CV) was found to produce cold soda pulps with the most promising combination of properties. This eucalypt produced pulps which had good bulk and excellent strength and optical properties.

In comparison, the *E. nitens* (NSW) and *E. regnans* both produced pulps with similar strength properties as the *E. nitens* (CV) pulp. However, these pulps had lower bulk and inferior optical properties. In particular, the brightness and light scattering coefficient of the *E. regnans* pulp was substantially lower than that of the *E. nitens* (CV) pulp. The *E. nitens* (CV and NSW) and *E. regnans* all had a similar refining energy demand to produce pulp of a given freeness or strength property.

The *E. fastigata* pulp had a substantially higher refining energy demand than the other eucalypts to produce pulp of a given freeness. When compared at a given freeness, the strength properties of the *E. fastigata* pulp were substantially lower than those of the other 15 year-old eucalypt pulps. The *E. fastigata* did, however, produce the brightest cold soda pulps.

The 8 year-old *E. nitens* (CV) had a shorter mean fibre length and higher lignin content than the 15 year-old *E. nitens* (CV). The pulp produced from the 8 year-old

wood, had bulk, strength and optical properties that were substantially lower than those of the pulp produced from the 15 year-old wood. The differences observed between the 8 and 15 year old *E. nitens* (CV) for the strength and optical properties were generally greater than the differences between the four, 15 year-old wood types.

INTRODUCTION

Extensive research and development over the past decade has established the viability of hardwood mechanical pulp as a low cost, high quality resource that can be used as a component of a wide range of paper grades, such as newsprint, paperboard and printing and writing papers (1,2). The greater wood yields per hectare and lower process power demands of hardwoods, relative to radiata pine, offers the New Zealand pulp and paper industry significant economic advantages. These advantages may be combined with the excellent performance of the smaller hardwood fibre for the manufacture of a wide range of quality papers (1).

Hardwood mechanical pulping knowledge in New Zealand is slight. Forest growers within the Eucalypt Breeding Co-operative require guidance on the potential value of the eucalyptus species to the mechanical pulping industry, to formulate their forest planting programmes. The pulp and paper industry also wishes to determine the suitability of short fibred, eucalyptus pulps as a means of improving product quality, such as paper formation and printing quality.

In this study the papermaking potential's of mechanical pulps produced from five selected eucalypt wood samples were assessed. Also, for one of these wood samples alternative mechanical pulping technologies were compared.

OUTLINE OF STUDY

Four eucalypt wood types have been identified as being suitable for plantation forestry in New Zealand. These are *E. nitens* (Central Victoria), *E. nitens* (NSW), *E. regnans* and *E. Fastigata*. This project was divided into two parts. This report covers the results from part one in which the mechanical pulping potential of these four eucalypt wood types were assessed using chip samples prepared from 15 year-old trees. An 8 year-old sample of the *E. nitens* (CV) was also evaluated. A standard cold soda treatment using a 40 g/L sodium hydroxide pulping liquor was used to compare the mechanical pulping response of these five wood types.

In part two, the 15 year-old *E. nitens* (CV) sample was evaluated over a wider range of process conditions. This involved evaluation of a second alkali application level for the standard cold soda treatment and comparison of the conventional cold soda process with the new alkaline peroxide mechanical pulping (APMP) process.

EXPERIMENTAL

Wood samples

A five tonne (oven-dry equivalent) sample of 15 year-old *E. nitens* (CV) and one tonne (oven-dry equivalent) samples of 15 year-old *E. nitens* (NSW), *E. regnans* and *E. fastigata* were obtained from Carter Holt Harvey Forests Ltd, Kinleith Forest. A one tonne (oven-dry equivalent) sample of 8 year-old *E. nitens* (CV) was obtained from Compartment 1090, Kaingaroa Forest. Full details of the origin and location of these five eucalypt wood types are given in Appendix A.

For each wood type, the stems were debarked and cut into 6.0m logs. Whole disks were cut from each log and analysed for moisture content, green density, basic density and stem heartwood content. Detailed results for each disk are given in Appendix B. Mean results for each wood type are given in Table 1.

Table 1: Wood Properties (based on whole disk measurements).

Property	*E. Nitens* (CV), 8yr	*E. Nitens* (CV), 15yr	*E. Nitens* (NSW), 15yr	*E. Regnans*, 15yr	*E. Fastigata*, 15yr
Moisture content*, %	126	122	138	155	139
Green density, kg/m^3	1059	1052	1090	1088	1133
Basic density, kg/m^3	468	474	461	426	479
Heart volume, %	30	51	58	38	38

* Moisture content = (weight of water/weight of oven-dry material x 100%)

The logs were chipped at the Timber Industry Training Centre using a four knife, 900mm, 55kW disc chipper. Oversize chips were removed in a 40 mm overs screen and returned to the chipper. Undersize chipped were removed through a 10 mm screen and rejected.

The wood properties of the chip samples for each wood type are given in Table 2

Table 2: Wood properties (based on chip sample measurement).

Property	*E. Nitens* (CV), 8yr	*E. Nitens* (CV), 15yr	*E. Nitens* (NSW), 15yr	*E. Regnans*, 15yr	*E. Fastigata*, 15yr
Chip density, kg/m^3	463	479	452	426	482
Oven-dry content*, %	47.3	46.8	43.0	41.5	45.5
DCM extractives, %	0.35	0.36	0.43	0.33	0.35
Klason lignin, %	26.2	23.4	22.4	21.7	26.5
Ash content, %	0.59	0.30	0.39	0.30	0.25
Chip fibre length, mm	0.64	0.77	0.78	0.81	0.75
Fibre coarseness, mg/m	0.053	0.057	0.071	0.076	0.059

* Oven-dry content = oven-dry weight/wet weight x 100%

The dichloromethane (DCM) extractives were determined using Appita standard P12s-79. The Klason lignin content and ash content of the extractive free wood were determined using Tappi standard T222 om-83 and T211 om-85, respectively. For each wood type, a kraft pulp of kappa number 20±2 was produced and bleached. Chip fibre length and fibre coarseness data were obtained from these kraft pulps using the Kajaani FS-200 fibre analyser. The experimental details for the kraft pulping and fibre dimension measurements are reported elsewhere (3).

Chip size distribution data for each wood type were determined using a Williams chip screen. Screening time was 5 minutes using a 3.0 kg (wet) sample size. The *E. nitens* (CV) produced more large chips than the other wood types which had similar chip size distributions, Figure 1. There was no apparent difference between the size distributions of the 8 and 15 year-old *E. nitens* (CV) samples.

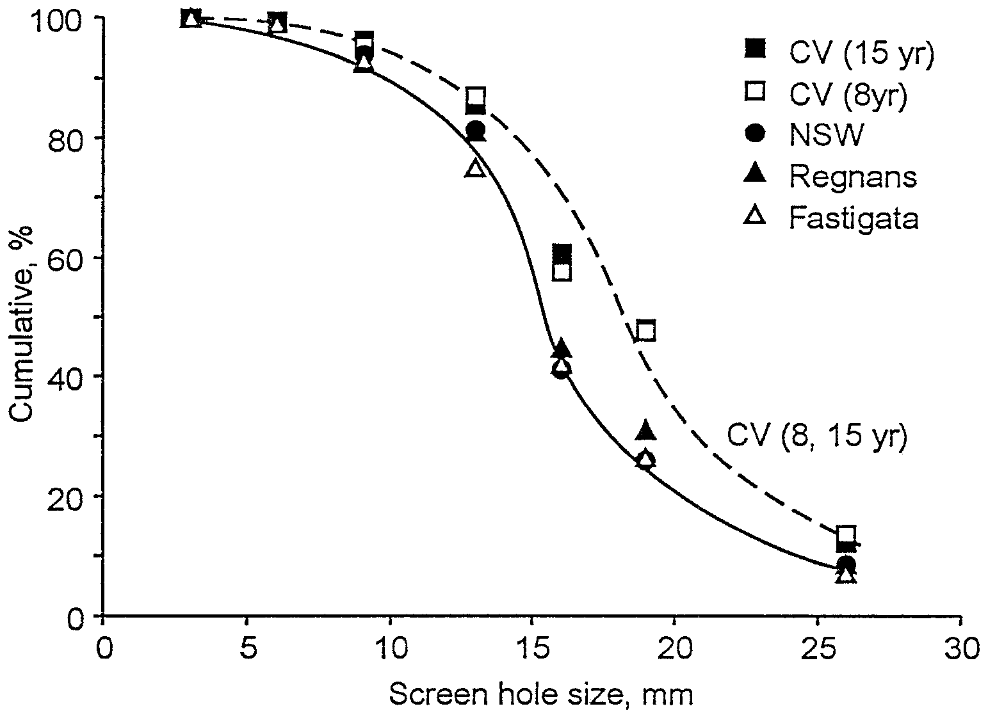

Figure 1: Cumulative chip size distributions as determined on a Williams screen.

Pulping

The pulping trials were performed in the NZ FRI Refiner Pilot Plant, Figure 2. This contains a Jylha SD 52/36, pressurised, 900 mm, 1250kW, 1500 rpm, single disc refiner that was used in this study and a Bauer 410, atmospheric, 1000mm, 400kW, 1500 rpm, double disc refiner.

To compare the mechanical pulping response of the five wood types a standard cold soda pulping treatment was used. This involved atmospherically steaming the chips at 80°C for five minutes before transferring them via a plug screw to the impregnator. A 40g/L sodium hydroxide liquor at 30°C was pumped to the impregnator at the required rate. A five minute retention time was maintained in the liquor impregnation stage. The chips were then returned to the atmospheric steaming bin where they were steamed for 20 minutes at 50°C prior to two stage refining.

For each wood type, generally three primary stage pulps were produced with energy consumption's in the range 700 to 850 kWh/odt. From each of these primary stage pulps at least three second stage pulps were produced with total energy consumption's in the range 1100 to 1800 kWh/odt.

The Jylha SD 52/36 refiner was operated with a 1.0 bar pressure in both refining stages and the refiner was fitted with plate pattern No. 205216.

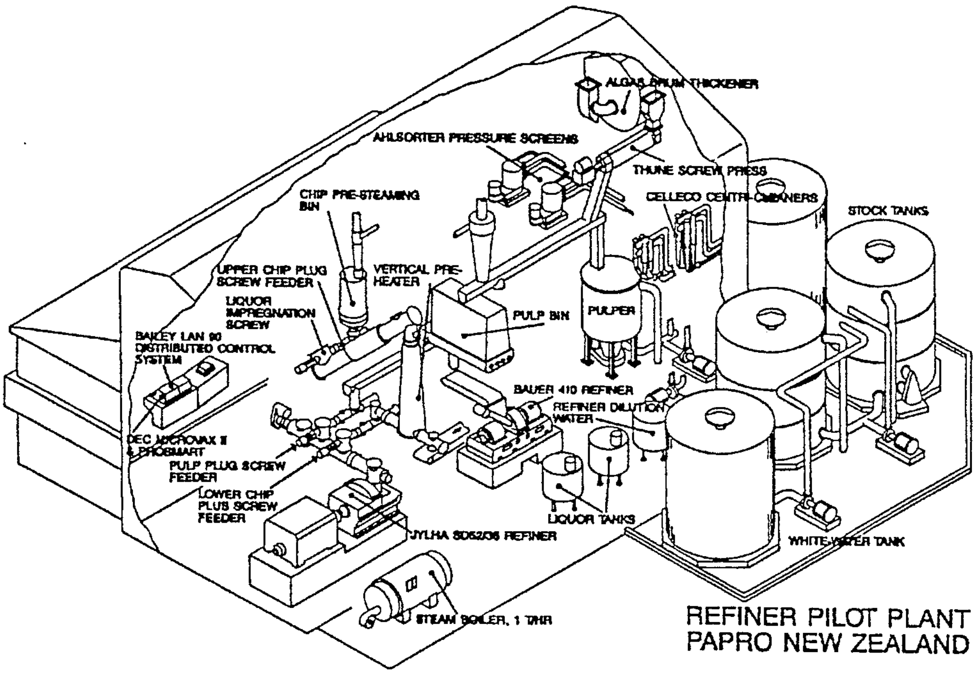

Figure 2: NZ FRI high-yield pulping pilot plant.

Pulp evaluation

A sample of impregnated chips was collected for each wood type to enable pulp yield to be determined. For each sample of impregnated chips, three 50 g (wet) sub-samples were taken and held in a water bath at 50°C for 15, 30 and 60 minutes. These sub samples were then disintegrated and washed with five litres of cold water. The wash water was filtered to recover fines. The washed fibre and fines were dried at 105°C to determine yield.

Pulp evaluation was performed after latency was removed from all pulps by disintegration at 90°C for 10 minutes at 1.25% stock consistency in a standard British disintegrator. Freeness and fibre classification were in accordance with Appita test method No. P206m-77 and Tappi Standard T233os-75, respectively. Pulp fibre length distributions and average pulp fibre lengths were determined using the Kajaani FS-200 fibre analyser fitted with a 0.15 mm screen plate.

Handsheets were prepared and evaluated in accordance with Appita test methods P203s-80 and P208m-75. The oven-dry basis weight was used to calculate the handsheet strength data. Light scattering coefficient was calculated using the air dry basis weight.

The pulp quality data are presented for each wood type in Appendix C, Tables C1 to C5. For all pulp properties, regression equations were used to provide interpolation of the data at a freeness of 200 CSF and an energy consumption of 1500 kWh/odt.

Pulp Bleaching

The peroxide bleach response of the cold soda pulp was determined for each wood type using pulps in the freeness range 190 to 240 CSF. The pulps were bleached according to PAPRO standard method 1.602. For the 15 year-old *E. nitens* (CV) pulp a range of alkali applications were used for each peroxide application, Table 5. The bleaching results for this wood type were then used to determine the best alkali applications for the other wood types.

After bleaching, the pulps were neutralised with H_2SO_3 to pH 5 at 1.0% consistency and brightness pads produced according to ISO standard 3688-1977.

RESULTS AND DISCUSSION

Chemical application and pulp yield

All the chips absorbed a similar amount of the 40 g/L sodium hydroxide liquor in the impregnator, Table 3. The *E. nitens* (CV) 15 yr, *E. nitens* (NSW) and *E. Fastigata*, all had an alkali absorption rate of approximately 8.2%. In comparison, the 8 year old *E. nitens* (CV) had a slightly lower absorption rate of 7.6% and the *E. regnans* a higher rate of 9.0%.

There was no substantial difference between the pulp yields of the different wood types for the impregnated chips that were cooked in the water bath at 50^{o}C for 15, 30 and 60 minutes. Generally the pulp yield decreased from 95.5% with 15 minutes cooking to 92.0% with 60 minutes cooking, Table 3 and Figure 3. Based on these measurements, the pilot plant cooking conditions of 50°C for 20 minutes would be expected to produce pulps with a yield of 94.6%.

Table 3: Chemical application and pulp yield data.

Wood type	Pulp No.	NaOH applied (%)	Pulp yield @ a given cooking time (%)		
			15 min	30 min	60 min
E. nitens (CV) 8 yr	94054	7.30			
	94099	7.78	96.8	93.8	92.2
	94103	7.78			
E. nitens (CV) 15 yr	94043	8.85			
	94081	8.05	96.8	93.8	92.2
	94085	8.05			
E. nitens (NSW) 15 yr	94059	8.15			
	94072	8.21	95.6	93.8	91.7
	94076	8.21			
E. regnans 15 yr	94039	9.51			
	94090	8.68	94.6	92.8	92.6
	94094	8.68			
E. Fastigata 15 yr	94047	8.18			
	94064	8.28	95.2	92.9	92.1

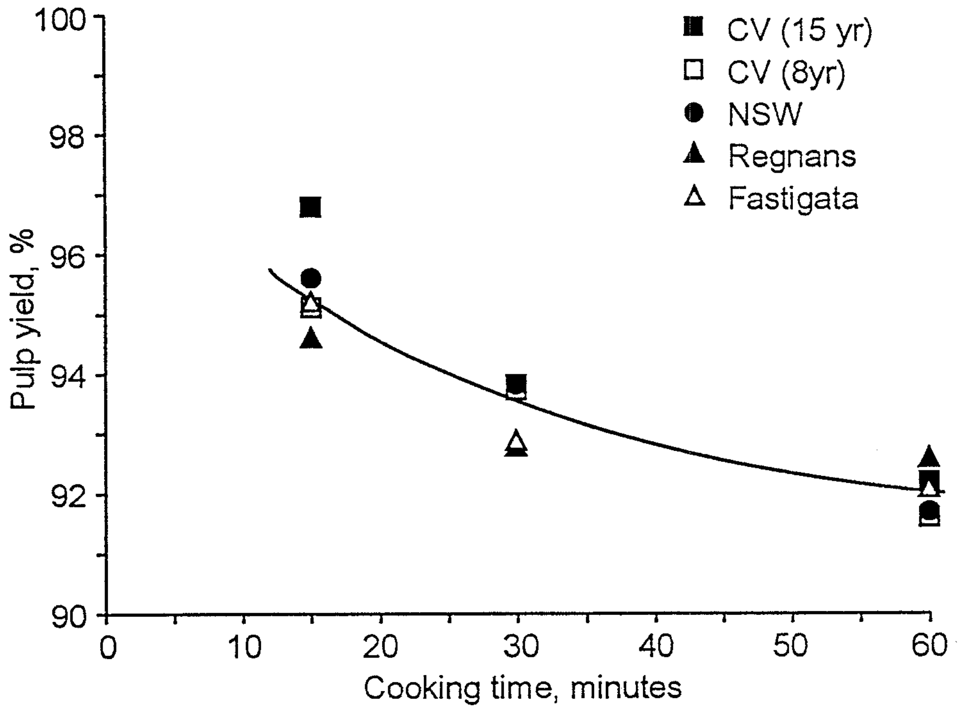

Figure 3: Pulp yield as a function of cooking time.

Energy consumption

The amount energy required to refine the chips to a given freeness was dependant on the eucalypt wood type, Figure 4. The *E. fastigata* chips had the highest energy demand of the five eucalypt wood types. At an energy consumption of 1500 kWh/odt, the cold soda pulp had a freeness of 240 CSF. In comparison, the 15 year-old *E. nitens* (CV), *E. nitens* (NSW) and *E. regnans* all had a similar energy demand to a given freeness. These wood types produce pulp with a freeness of 195 CSF at 1500 kWh/odt. The 8 year-old *E. nitens* (CV) had the lowest energy demand and at an energy consumption of 1500 kWh/odt produced a 175 CSF pulp.

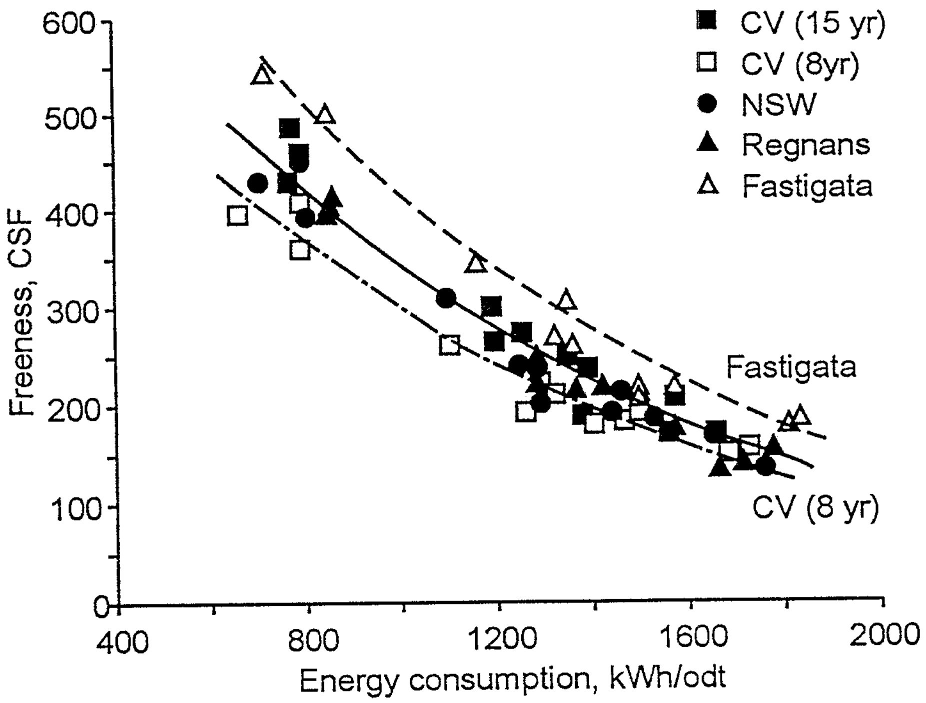

Figure 4: Freeness as a function of energy consumption.

Shive content and fibre distribution

There was no apparent difference between the shive contents of the *E. nitens* (NSW), *E. regnans* and *E. Fastigata* pulps when compared at a given freeness, Figure 5. The *E. nitens* (CV) produced pulps with the lowest shive content. For the 15 year-old *E. nitens*, the differences in shive content were most noticeable at high freeness. Below 300 CSF, its shive content was only marginally lower than those of the other 15 year-old eucalypt wood types. The 8 year-old *E. nitens* produced pulp with the lowest shive content. At 200 CSF, the 8 year-old *E. nitens* had a shive content of 0.07% compared to the 0.29% obtained with the 15 year-old eucalypt samples.

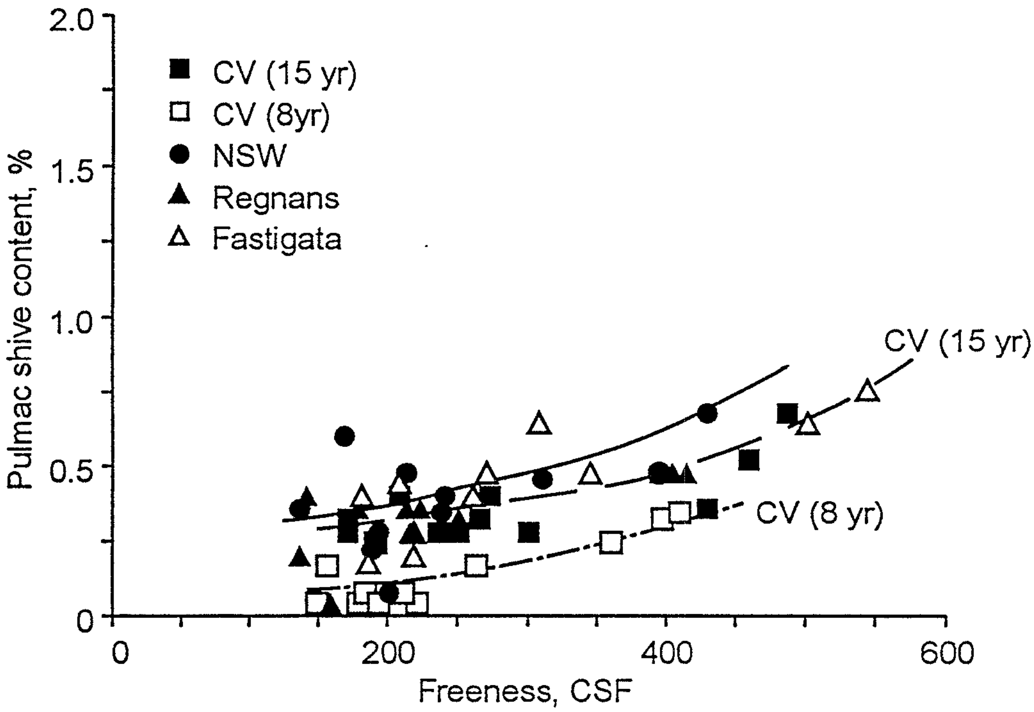

Figure 5: Pulmac shive content (0.15mm screen plate) as a function of freeness.

The considerable differences between the fibre lengths measured in the eucalypt chips for the five wood types (Table 2) are reflected in the mean length weighted fibre lengths of the cold soda pulps when compared at a given freeness, Figure 6. At 200 CSF, the *E. regnans* pulp had the longest mean fibre length of 0.80 mm. The 15 year-old *E. nitens* (CV) and (NSW) both had a mean fibre length of 0.76 mm. Of the 15 year-old wood samples, the *E. fastigata* pulp had the shortest mean length of 0.74 mm.

The mean fibre length of the *E. nitens* (CV) decreased substantially when the wood age was decreased. At 200 CSF, the 8 year-old sample had a mean fibre length of only 0.66 mm.

The mass proportion of long fibre as determined by the Bauer McNett classifier showed similar differences between the five eucalypt wood types as the mean fibre length data, Figure 7. The *E. regnans* and 15 year-old *E. nitens* wood types had the highest proportion of material retained on the 50 mesh (R_{50}) screen. As expected, from the fibre length data, the 8 year-old *E. nitens* (CV) had lowest long fibre content.

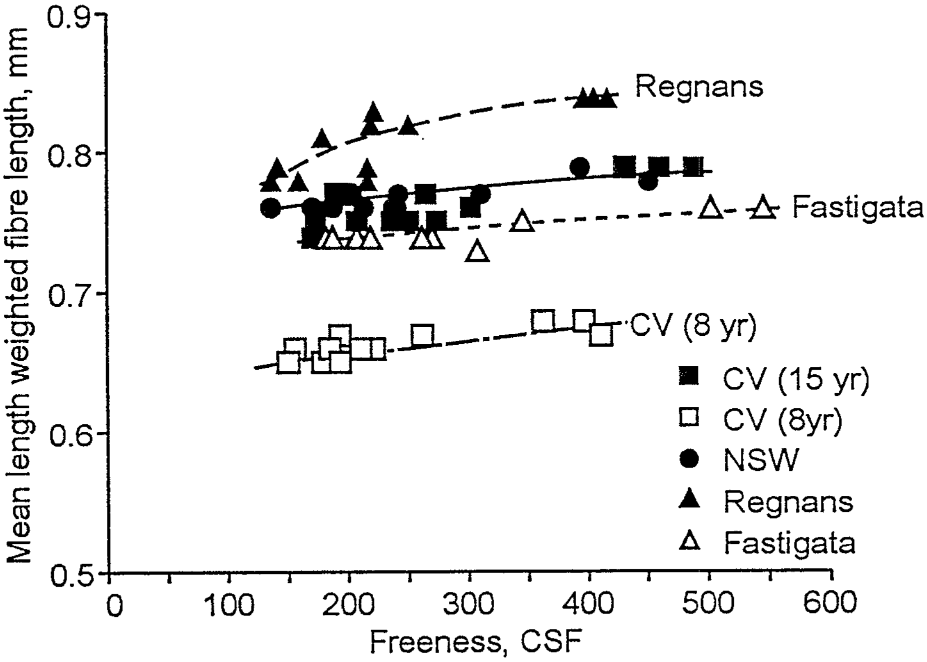

Figure 6: Mean length weighted fibre length as a function of freeness.

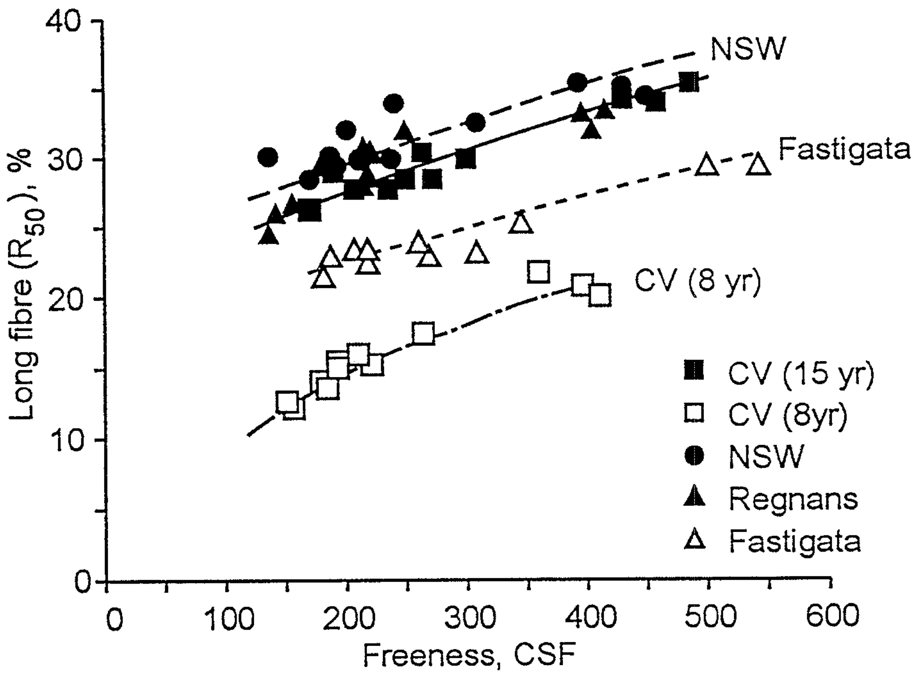

Figure 7: Bauer McNett R_{50}, long fibre fraction as a function of freeness.

The Bauer McNett fines content shows the reverse trend to the long fibre content. The 8 year-old *E. nitens* (CV) contained the largest amount of material that passed through the Bauer McNett 200 mesh screen (P_{200}). The *E. regnans* and *E. nitens* (NSW) produced pulps that had the lowest fines content of the five eucalypt wood types, Figure 8.

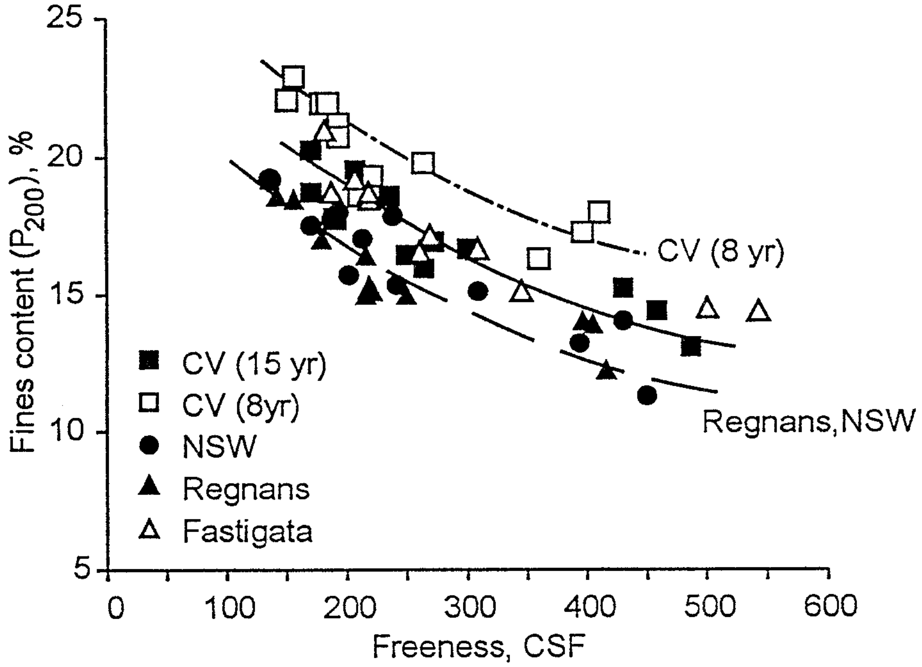

Figure 8: Bauer McNett P_{200}, fines fraction as a function of freeness.

HANDSHEET PROPERTIES

Handsheet properties have been plotted against freeness. In addition, selected properties have been plotted against tensile index and energy consumption. The use of tensile index as a basis of comparison recognises the importance of this parameter as an indicator of sheet bonding and runnability. A summary of the handsheet properties at 200 CSF is presented Table 4.

TABLE 4: Summary of pulp and handsheet properties at 200 CSF.

Wood type	*E. nitens* (CV) 8 yr	*E. nitens* (CV) 15 yr	*E. nitens* (NSW) 15 yr	*E. regnans* 15 yr	*E. fastigata* 15 yr
Energy input, kWh/odt	1374	1460	1460	1460	1675
Pulmac shives (0.15), %	0.07	0.29	0.29	0.29	0.29
Mean fibre length, mm	0.66	0.76	0.76	0.80	0.74
Long fibre (R_{30}), %	15.1	28.3	30.5	28.3	22.6
Fines (P_{200}), %	20.6	18.9	16.9	16.9	18.9
Handsheet property					
Bulk, cm^3/g	2.02	2.16	2.02	2.02	2.16
Air resistance, s/100ml	13.2	13.2	17.2	17.2	8.8
Tensile index, Nm/g	41.6	46.9	46.9	46.9	41.6
Tear index, $mN.m^2/g$	5.3	7.2	7.2	7.2	5.6
Brightness, %	46.0	49.0	49.0	47.2	50.9
Scattering coeff., m^2/kg	49.3	49.3	48.6	44.2	47.9
Opacity, %	96.7	96.7	96.7	94.8	95.0

Sheet consolidation

The 15 year-old *E. nitens* (CV) and *E. Fastigata* both produced cold soda pulps that were substantially more bulky than the other eucalypt pulps when compared on the basis of both freeness and energy consumption, Figures 9 and 10, respectively. Although the *E. regnans* and *E. nitens* (NSW) pulps contained more long fibre than the pulps produced from other 15 year-old eucalypts, they consolidated to a similar bulk as the 8 year-old *E. nitens* (CV) which had lowest long fibre content.

When compared on the basis of tensile strength, the cold soda pulp produced from the 8 year-old *E. nitens* (CV) produced the pulp with the lowest bulk, Figure 11. The *E. nitens* (NSW), *E. regnans* and *E. fastigata* pulps all had a similar bulk. At a tensile index of 45 Nm/g these pulps had a bulk of 2.08 cm^3/g compared to the 2.00 cm^3/g obtained for the 8 year-old *E. nitens* (CV).

For the *E. nitens* (CV) pulps, increasing the wood age from 8 to 15 years substantially increased the bulk. At 45 Nm/g the pulp produced from the 15 year-old *E. nitens* (CV) had the highest bulk of 2.20 cm^3/g.

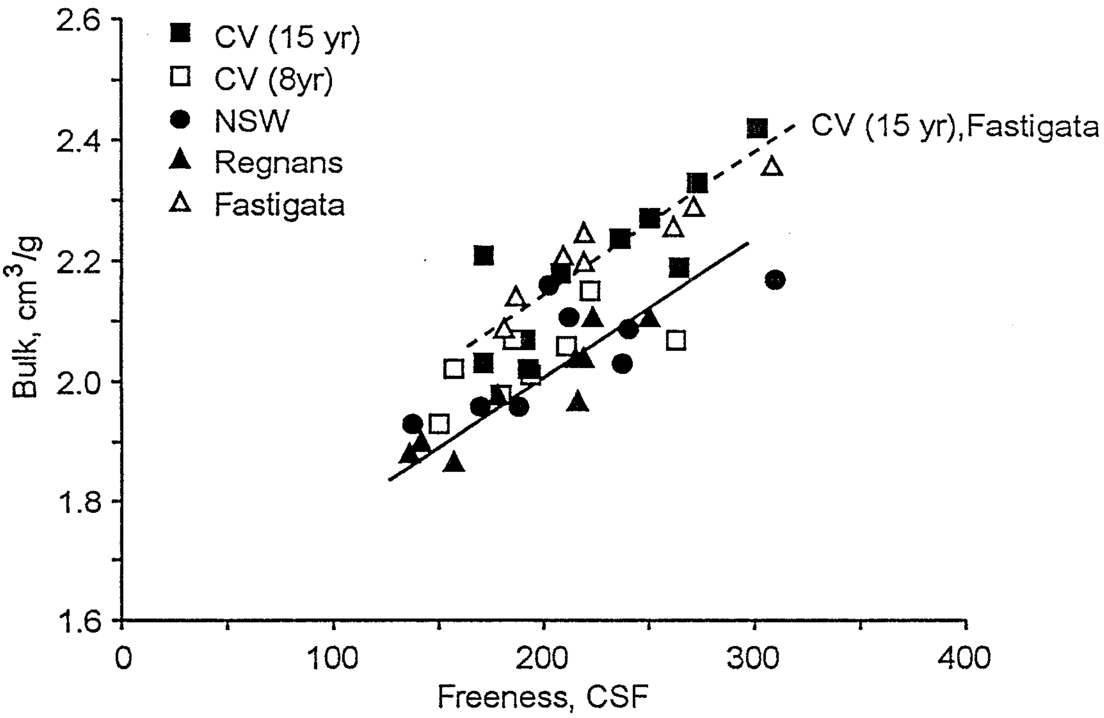

Figure 9: Bulk as a function of freeness.

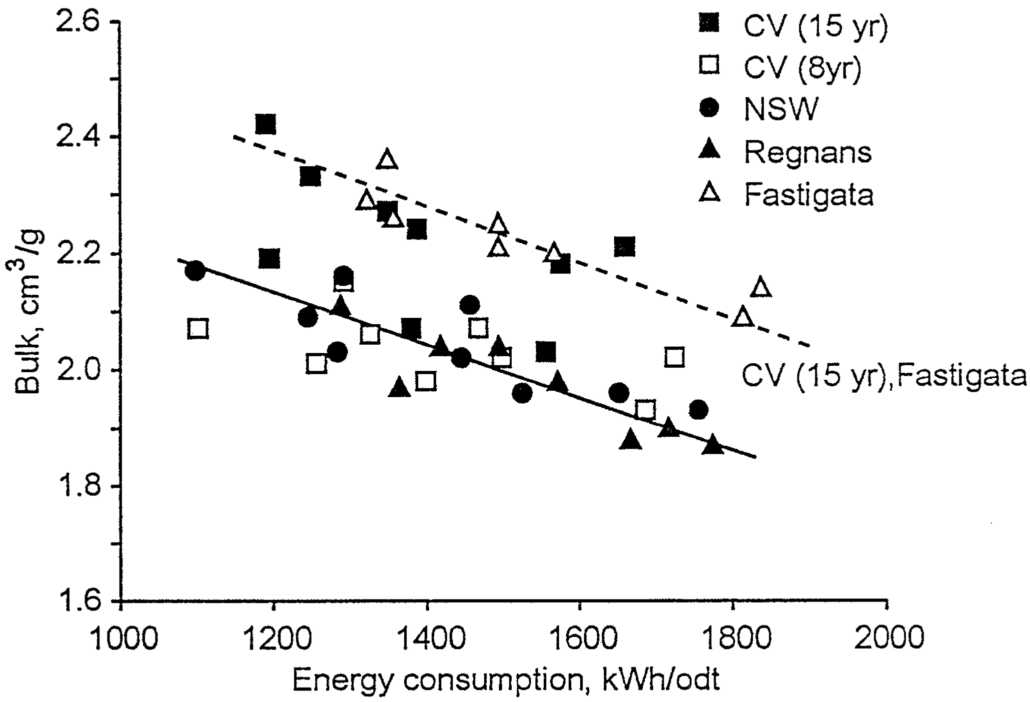

Figure 10: Bulk as a function of energy consumption.

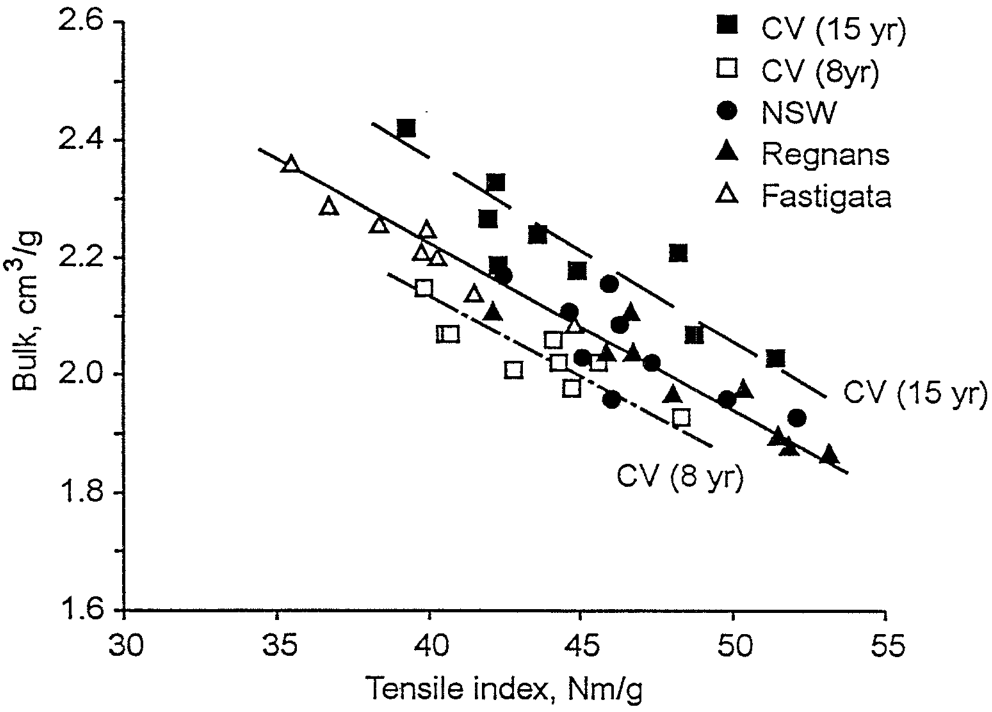

Figure 11: Bulk as a function of tensile index.

Sheet strength properties.

The pulps produced from the 15 year old *E. nitens* (CV and NSW) and *E. regnans* all achieved a similar tensile strength at a given freeness, Figure 12. In comparison, the tensile strength of the *E. fastigata* pulp was substantially lower than that of the other 15 year-old eucalypts. For the *E. nitens* (CV), decreasing the wood age from 15 to 8 years decreased the tensile strength of the pulp to the same level as that of the *E. fastigata* pulp.

When compared at a specific energy consumption, the *E. regnans* and *E. nitens* (NSW) had the highest tensile strength, Figure 13. Both the 8 and 15 year-old *E. nitens* (CV) had a similar tensile strength for a given energy input that was slightly lower than that of the *E. nitens* (NSW). In comparison, the tensile strength of the *E. fastigata* was substantially lower than that of all the other eucalypts.

For the 15 year-old eucalypts, the higher mean fibre lengths of the *E. regnans* and *E. nitens* (CV and NSW) pulps gave them superior tear strength to the *E. fastigata* pulp, Figure 14. The 8 year-old *E. nitens* (CV) pulp which had a shorter mean fibre length than all the 15 year-old eucalypts also had a lower tear strength.

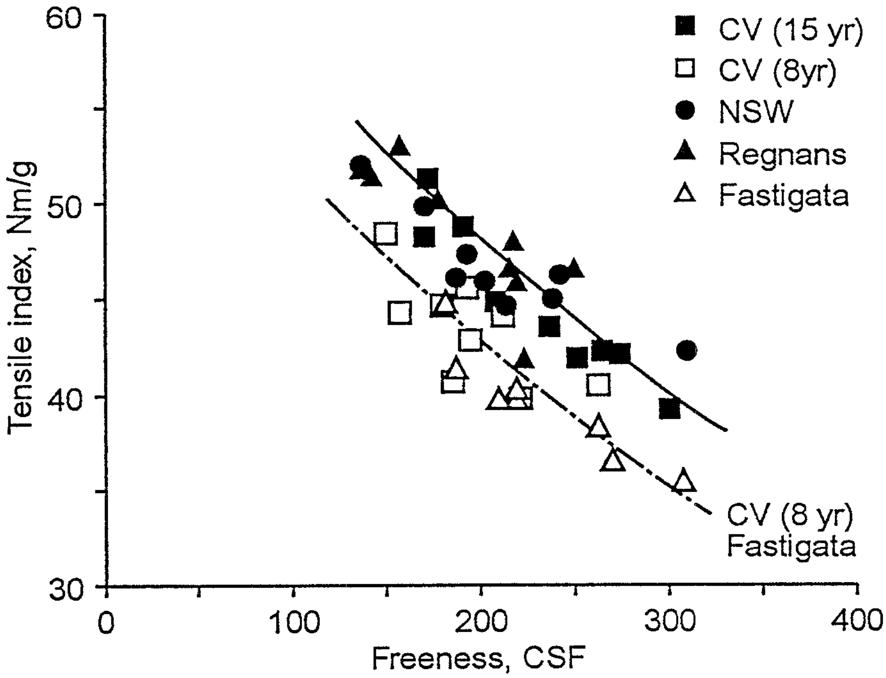

Figure 12: Tensile strength as a function of freeness

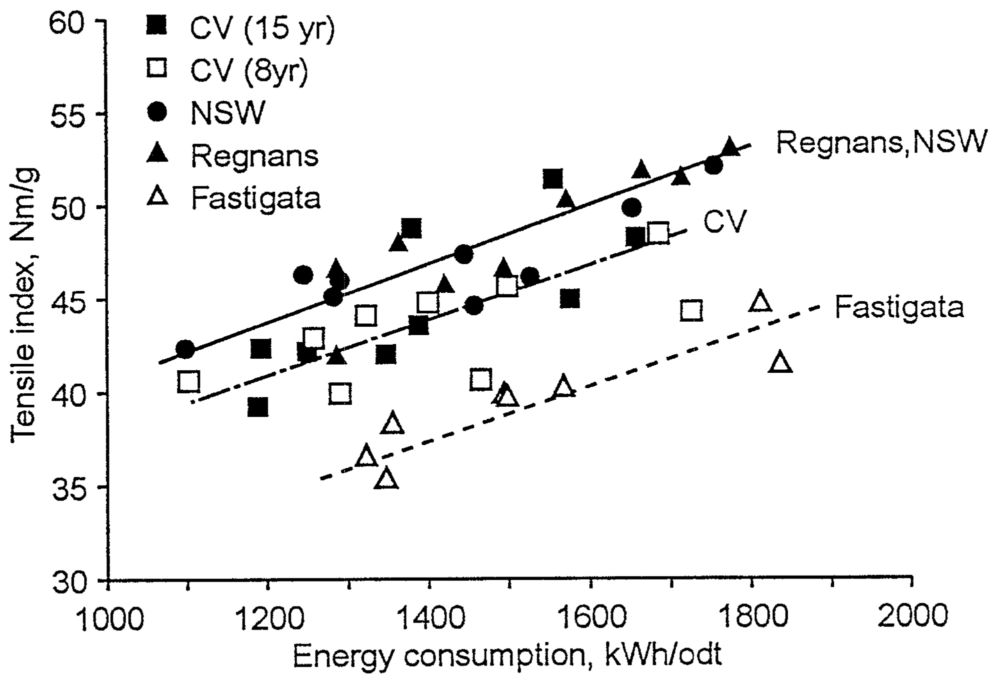

Figure 13: Tensile strength as a function of energy consumption

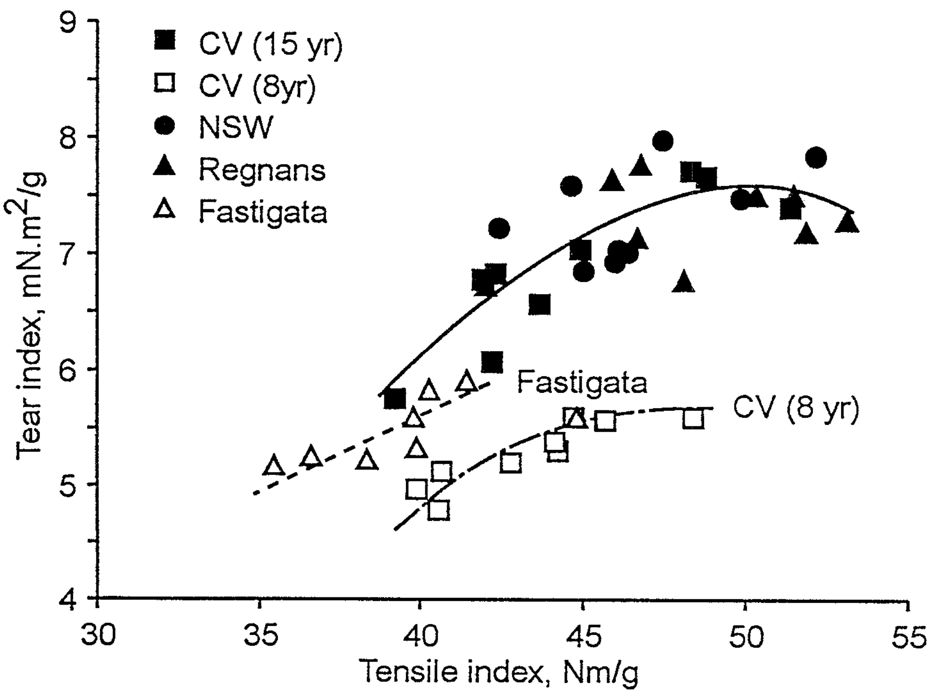

Figure 14: Tear strength as a function of tensile index

Optical properties and peroxide bleach response.

In contrast to the trends observed for the strength properties, *E.fastigata* produced pulps with the highest brightness, Figure 15. At 200 CSF, the *E.fastigata* pulp had a handsheet brightness of 50.9%. The 15 year-old *E. nitens* (CV and NSW) both produced pulp which were approximately 2.0 percentage points lower in brightness than the *E.fastigata* pulp. The *E. regnans* produced pulp with the lowest brightness of the 15 year-old wood samples. At 200 CSF, this pulp had a brightness of only 47.2%.

Wood age had a major effect on the brightness of the *E. nitens* (CV) pulps and the pulps produced from the 8 year-old wood were 3.0 percentage points lower in brightness than the pulps produced from the 15 year-old wood.

Three hydrogen peroxide applications of 1.0, 2.5 and 4.0% were used to determine the bleach response of each eucalypt wood type. The influence of alkalinity on the bleaching response was determined for the 15 year-old *E. nitens* (CV) by evaluating three alkali applications for each peroxide application, Table 5. The bleaching results for this wood type were then used to determine the best alkali applications for the other wood types.

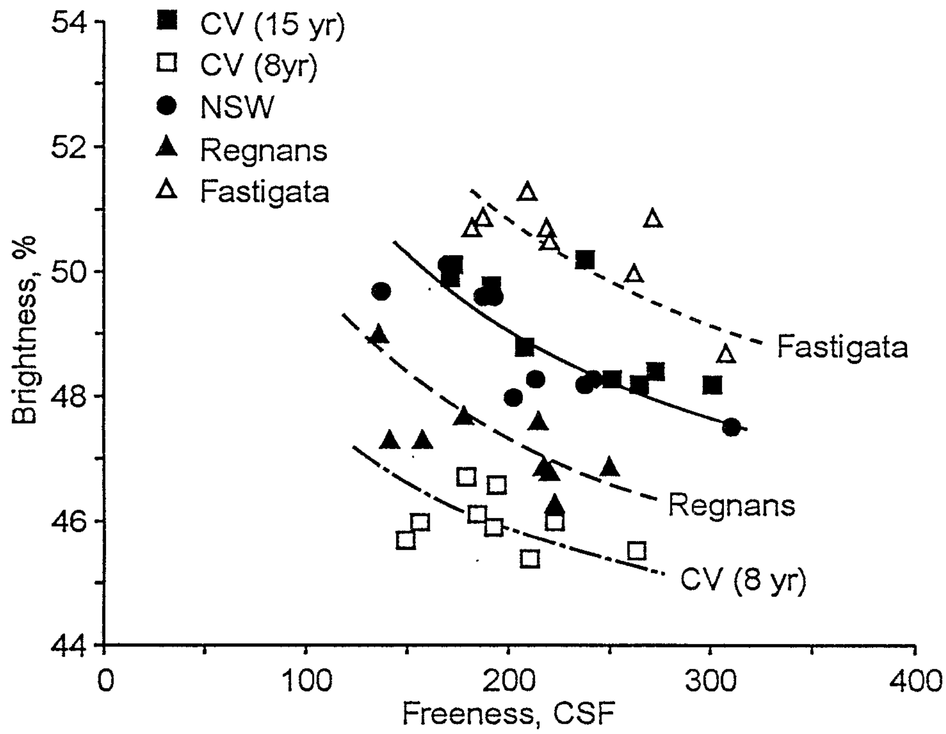

Figure 15: Handsheet brightness as a function of freeness.

TABLE 5: Bleaching conditions and ISO brightness for the 15 year-old *E. nitens* (CV) pulp.

Pulp Number	Freeness (CSF)	H_2O_2 (%)	NaOH (%)	Final pH	ISO-brightness (%)
94045	191	0.0	0.00		50.2
		1.0	0.75	10.1	59.8
		1.0	1.00	10.3	59.2
		1.0	1.25	10.9	57.8
		2.5	2.00	11.0	61.9
		2.5	2.50	11.8	61.1
		2.5	3.00	12.0	60.1
		4.0	3.50	12.1	63.4
		4.0	4.00	10.9	62.0
		4.0	4.50	12.5	63.5

For the 15 year-old *E. nitens* (CV) pulp, the highest brightness was obtained using the lowest sodium hydroxide application. Based on these results sodium hydroxide applications of 0.75, 2.00 and 3.50% were used to bleach the remaining eucalypts pulps with 1.0, 2.5 and 4.0% peroxide, respectively, Table 6.

TABLE 6: Bleaching conditions and ISO Brightness data for all eucalypt wood types.

Wood type	Pulp Number	Freeness (CSF)	H_2O_2 (%)	NaOH (%)	Final pH	ISO-brightness (%)
E.nitens (CV) 15 yr	94045	191	0.0	0.00		50.2
			1.0	0.75	10.1	59.8
			2.5	2.00	11.0	61.9
			4.0	3.50	12.1	63.4
E.nitens (CV) 8 yr	94056	194	0.0	0.00		46.9
			1.0	0.75	10.3	57.0
			2.5	2.00	12.0	56.6
			4.0	3.50	12.7	57.9
E.nitens (NSW) 15 yr	94061	238	0.0	0.00		49.7
			1.0	0.75	10.7	56.5
			2.5	2.00	11.8	58.8
			4.0	3.50	12.6	61.3
E.regnans 15 yr	94041	220	0.0	0.00		48.1
			1.0	0.75	10.6	56.7
			2.5	2.00	11.9	57.9
			4.0	3.50	12.7	60.1
E. fastigata 15 yr	94051	219	0.0	0.00		50.7
			1.0	0.75	10.0	61.8
			2.5	2.00	11.0	63.0
			4.0	3.50	12.5	62.5

NB. All bleachings had >99.5% H_2O_2 consumed.

In terms of their final brightness, the bleached pulps followed a similar trend to that observed for the unbleached handsheet brightness values, Figure 16. The *E. fastigata* and 15 year-old *E. Nitens* (CV) produced the brightest bleached pulps and the 8 year-old *E. nitens* (CV) produced the darkest bleached pulp. However, all pulps showed a similar increase in pulp brightness with peroxide bleaching. Generally, for each wood type, a 4.0% hydrogen peroxide application gave an increase in brightness of 11 to 12 percentage points over the original unbleached brightness level. This brightness gain was considerably lower than expected as other researchers have shown that brightness gains of up to 30 percentage points have been obtained for eucalypts with a 4.0% peroxide application (4). The fact that 99.5% of the applied peroxide was consumed for all the bleached pulps suggests that low brightness gain was due the alkali application being too high. Further work is required to optimise the bleaching conditions for the New Zealand-grown eucalypts.

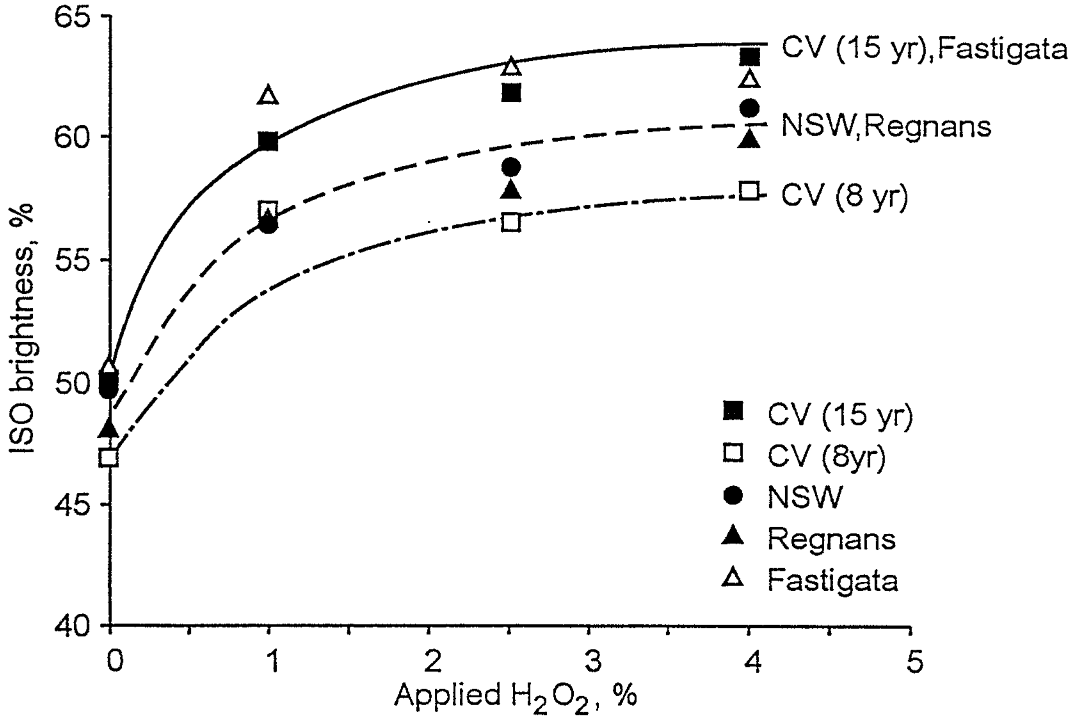

Figure 16: The peroxide bleach response.

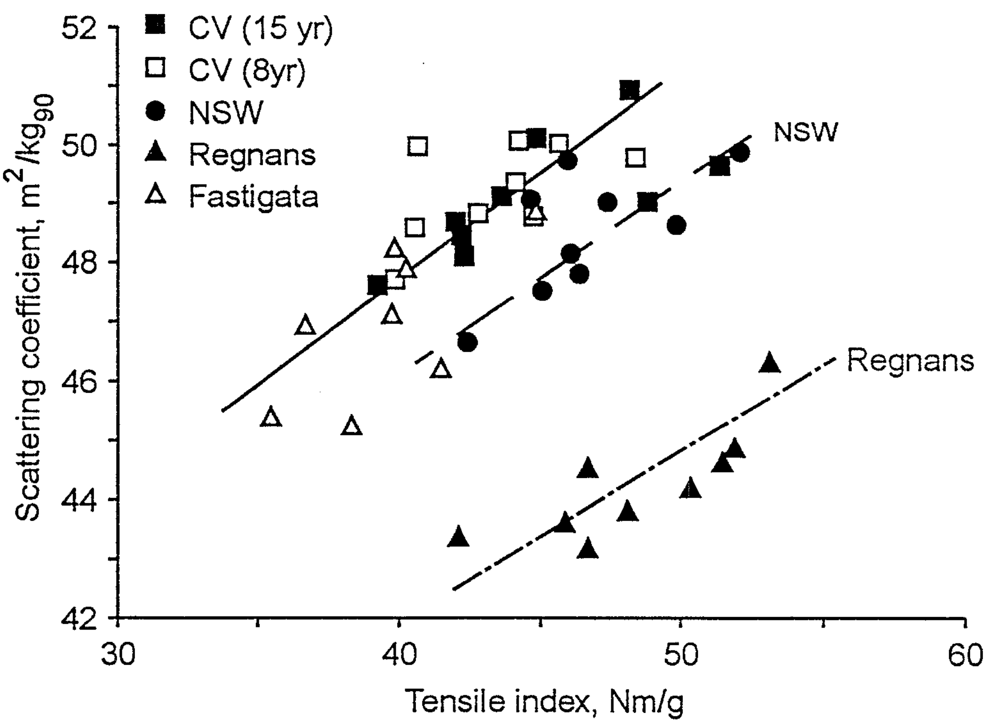

Figure 17: Light scattering coefficient as a function of tensile index.

The *E. fastigata* and the 8 and 15 year-old *E. nitens* (CV) produced pulps with the highest light scattering coefficient, Figure 17. At a tensile index of 45 Nm/g these pulps had a scattering coefficient of 49.1 m^2/kg. The *E. nitens* (NSW) had a slightly lower scattering coefficient of 48.1 m^2/kg at the same tensile index. Although the *E. regnans* produced a pulp with low bulk and good strength properties, it scattering coefficient was substantially lower than that of the other eucalypts. At 45 Nm/g the scattering coefficient of the *E. regnans* was only 43.5 m^2/kg. The lower scattering coefficient of the *E. nitens* (NSW) and *E. regnans* pulp can probably be attributed in part to their lower fines content.

CONCLUSIONS

This study has identified important differences in the mechanical pulping responses of four eucalypt wood types that are suitable for plantation forestry in New Zealand. The influence of wood age on pulp properties for one wood type has also been determined.

When cold soda pulps were prepared from the four wood types using 15 year-old trees, the *E. nitens* (CV) was found to produce pulps with the most promising combination of properties. This eucalypt produced pulps which had good bulk and excellent strength and optical properties.

The *E. nitens* (NSW) and *E. regnans* both produced pulps with similar strength properties as the *E. nitens* (CV) pulp. However, these pulps had lower bulk and inferior optical properties. In particular, the brightness and light scattering coefficient of the *E. regnans* pulp was substantially lower than that of the *E. nitens* (CV) pulp. The *E. fastigata* pulp had a substantially higher refining energy demand than the other eucalypts and had lower strength properties. The *E. fastigata* did, however, produce the brightest cold soda pulps.

The 8 year-old *E. nitens* (CV) had a shorter mean fibre length and higher lignin content compared to the 15 year-old *E. nitens* (CV). The pulp produced from the 8 year-old wood had bulk, strength and optical properties that were substantially lower than those of the pulp produced from the corresponding 15 year-old wood. The differences observed between the 8 and 15 year old *E. nitens* (CV) for the strength and optical properties were generally greater than the differences between the four, 15 year-old wood types.

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APPENDIX A

ORIGIN AND LOCATION OF EUCALYPT WOOD TYPES

ORIGIN AND LOCATION OF EUCALYPT WOOD TYPES

E. nitens (Central Victoria), 8 yr old

Cpt 1090 Kaingaroa, FRI trial RO2043
Established 1986, Seedlot, 8/0/85/06 Mt Toorongo Plateau, Victoria.

E. nitens (Central Victoria), 15 yr old

CHH Forests Ltd, Kinleith Forest
E. nitens seed stand, Tram Rd, 6236/623716
Established 1979 Rubicon, Toorongo, McAlister mix.

E. nitens (NSW), 15 yr old

CCH Forests Ltd, Kinleith Forest
Maire Rd Provenance/Species Trial, 6217/621710
Established 1977 at 1666 sph, thinned age 7 to 625 sph. Nimmitabel source.

E. regnans, 15 yr old

CCH Forests Ltd, Kinleith Forest
Maire Rd Provenance/Species Trial, 6217/621710
Established 1977 at 1666 sph, thinned age 7 to 625 sph. Kinleith source.

E. Fastigata, 15 yr old

CCH Forests Ltd, Kinleith Forest
Maire Rd Provenance/Species Trial, 6217/621710
Established 1977 at 1666 sph, thinned age 7 to 625 sph. Oberon (NSW) source.

APPENDIX B

WOOD PROPERTY DATA
WHOLE DISK MEASUREMENTS

WOOD PROPERTY DATA
WHOLE DISK MEASUREMENTS

TABLE B1: *E. niten* (CV) 8 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
1	1	222	135	4.8	0.12	33	472	1097	133
1	2	135	84	4.7	0.05	40	438	1025	135
1	Tree	222	84	9.5	0.168	36	463	1078	133
2	1	233	163	5.5	0.17	41	462	1079	133
2	2	163	77	5.4	0.06	17	455	1045	129
2	Tree	233	77	10.9	0.235	38	460	1070	132
3	1	215	134	5.2	0.13	38	501	1105	120
3	2	134	77	5.5	0.05	20	466	1032	121
3	Tree	215	77	10.7	0.176	30	492	1085	120
4	1	294	176	7	0.31	42	486	1091	124
4	2	176	79	7.1	0.1	20	473	1015	114
4	Tree	294	79	14.1	0.405	36	483	1073	121
6	1	207	148	5.2	0.13	31	499	1073	114
6	2	148	78	5.5	0.06	17	509	1063	108
6	Tree	207	78	10.7	0.187	26	502	1070	112
8	1	183	125	5.7	0.11	27	464	1073	131
8	2	125	73	5.7	0.04	0	444	1022	130
8	Tree	183	73	11.4	0.152	19	458	1058	131
9	1	246	158	6.8	0.22	36	446	1023	129
9	2	158	80	6.8	0.08	13	475	1008	112
9	Tree	246	80	13.6	0.3	30	453	1019	124
11	1	222	140	6	0.16	25	465	1076	131
11	2	140	85	6	0.06	0	457	1004	119
11	Tree	222	85	12	0.218	21	462	1056	127
12	1	224	144	6.6	0.18	44	476	1077	126
12	2	144	72	6.7	0.06	33	437	987	125
12	Tree	224	72	13.3	0.242	38	466	1053	126
13	1	279	184	6	0.26	35	441	1075	143
13	2	184	100	5.9	0.1	10	443	1052	137
13	Tree	279	100	11.9	0.352	27	441	1069	141
14	1	320	198	7.5	0.4	38	513	1131	120
14	2	198	88	7.7	0.13	23	491	1082	120
14	Tree	320	88	15.2	0.532	34	507	1119	120
16	1	200	124	5.6	0.12	42	467	1078	131
16	2	124	64	5.6	0.04	25	438	1029	135
16	Tree	200	64	11.2	0.158	35	460	1066	132

TABLE B1 (continued): *E. niten* (CV) 8 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
17	1	236	156	6.9	0.21	33	453	1050	132
17	2	156	78	6.9	0.08	13	450	1011	125
17	Tree	236	78	13.8	0.288	29	452	1040	130
18	1	216	147	6.4	0.17	41	459	1063	131
18	2	147	82	6.4	0.07	14	467	1059	127
18	Tree	216	82	12.8	0.235	35	461	1061	130
19	1	209	140	5.9	0.14	36	450	1049	133
19	2	140	74	5.9	0.05	20	438	998	127
19	Tree	209	74	11.8	0.198	29	447	1035	131
20	1	210	133	6.4	0.15	40	466	1088	134
20	2	133	70	6.3	0.05	20	490	1055	115
20	Tree	210	70	12.7	0.203	30	472	1080	129
21	1	237	152	7.4	0.22	36	463	972	109
21	2	152	67	7.3	0.07	14	481	938	95
21	Tree	237	67	14.7	0.296	31	468	964	106
22	1	268	165	6.3	0.24	29	493	1099	122
22	2	165	73	6.3	0.07	14	480	1039	116
22	Tree	268	73	12.6	0.31	26	490	1085	121
25	1	206	128	5.2	0.12	42	458	1061	131
25	2	128	90	5.3	0.05	0	483	1036	114
25	Tree	206	90	10.5	0.166	32	466	1054	126
24A	1	217	150	5.5	0.15	33	469	1060	125
24A	2	150	84	5.5	0.06	17	478	1059	121
24A	Tree	217	84	11	0.208	30	472	1060	124
24B	1	186	131	5.6	0.11	27	450	1051	134
24B	2	131	85	5.6	0.05	0	471	1054	125
24B	Tree	186	85	11.2	0.164	19	456	1052	131
Mean	1	230	149	6	0	36	469	1070	128
Mean	2	149	79	6	0	16	465	1029	121
Mean	Tree	230	79	12	0	30	468	1059	126

TABLE B2: *E. nitens* (CV) 15 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
1	1	184	137	6	0.12	17	453	1038	128
1	2	137	101	6	0.07	14	470	990	110
1	3	101	55	7.1	0.03	0	514	1013	96
1	Tree	184	55	19.1	0.224	14	468	1020	118
2	1	204	157	6	0.15	67	410	1016	147
2	2	157	101	6	0.08	63	424	982	131
2	3	101	50	6.4	0.03	67	465	992	114
2	Tree	204	50	18.4	0.264	65	420	1003	139
3	1	226	177	6	0.19	68	452	1026	127
3	2	177	136	6	0.12	58	483	1017	110
3	3	136	70	7.5	0.06	33	509	1041	104
3	Tree	226	70	19.5	0.373	57	472	1026	118
4	1	278	212	6	0.28	64	519	1103	112
4	2	212	175	6	0.18	61	510	1061	108
4	3	175	140	5.2	0.1	40	531	1085	104
4	4	140	78	5.7	0.05	0	555	1093	96
4	Tree	278	78	22.9	0.618	53	521	1087	108
5	1	234	184	6	0.21	52	426	1040	143
5	2	184	133	6	0.12	42	433	1009	132
5	3	133	75	5.2	0.05	20	488	1062	118
5	Tree	234	75	17.2	0.372	45	436	1033	137
6	1	159	118	6	0.09	67	446	1048	135
6	2	118	65	7.2	0.05	40	483	1019	111
6	Tree	159	65	13.2	0.14	56	459	1038	127
7	1	245	189	6	0.22	59	456	1059	131
7	2	189	150	6	0.14	50	489	1057	116
7	3	150	78	8.7	0.09	22	521	1066	104
7	Tree	245	78	20.7	0.451	49	479	1060	121
8	1	271	210	6	0.27	56	463	1072	131
8	2	210	172	6	0.17	53	500	1059	111
8	3	172	144	6	0.12	42	542	1077	98
8	4	144	77	5	0.05	20	560	1082	93
8	Tree	271	77	23	0.614	48	497	1070	116
9	1	275	160	6	0.23	52	445	1122	152
9	2	160	118	6	0.09	33	448	1051	134
9	3	118	59	5.9	0.04	0	465	1042	124
9	Tree	275	59	17.9	0.357	41	448	1095	144

TABLE B2 (continued): *E. nitens* (CV) 15 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
10	1	242	178	6	0.21	52	469	1112	137
10	2	178	132	6	0.11	45	501	1087	117
10	3	132	75	5.5	0.05	20	539	1087	101
10	Tree	242	75	17.5	0.371	44	488	1101	126
11	1	299	240	6	0.34	56	437	1051	139
11	2	240	203	6	0.23	48	469	1042	122
11	3	203	163	6	0.16	44	502	1060	111
11	4	163	87	5.9	0.07	14	518	1052	102
11	Tree	299	87	23.9	0.808	47	467	1050	125
12	1	230	182	6	0.2	55	466	1038	122
12	2	182	151	6	0.13	38	484	1009	108
12	3	151	108	5.5	0.07	29	512	1016	98
12	4	108	73	4.5	0.03	0	543	1033	90
12	Tree	230	73	22	0.434	41	485	1025	111
13	1	340	254	6	0.42	64	490	1111	126
13	2	254	203	6	0.25	60	507	1091	115
13	3	203	145	6	0.14	50	527	1082	104
13	4	145	97	4.2	0.05	20	526	1072	103
13	Tree	340	97	22.2	0.859	58	503	1098	118
14	1	175	136	6	0.11	73	465	1034	122
14	2	136	109	6	0.07	57	497	1013	103
14	3	109	67	7.3	0.05	20	539	1050	94
14	Tree	175	67	19.3	0.231	56	489	1031	111
15	1	395	304	6	0.58	57	436	1063	144
15	2	304	255	6	0.37	54	470	1048	123
15	3	255	205	6	0.25	52	488	1068	118
15	4	205	96	7.2	0.13	23	491	1031	109
15	Tree	395	96	25.2	1.332	52	461	1057	130
16	1	301	230	6	0.33	61	469	1099	134
16	2	230	199	6	0.22	50	488	1076	120
16	3	199	94	8.8	0.15	33	516	1062	105
16	Tree	301	94	20.8	0.706	51	485	1084	123
17	1	223	178	6	0.19	63	475	1075	126
17	2	178	135	6	0.12	58	500	1051	110
17	3	135	71	7.7	0.07	29	529	1043	97
17	Tree	223	71	19.7	0.373	54	492	1062	116
19	1	168	145	6	0.12	50	433	1011	134
19	2	145	109	6	0.08	38	485	1029	112
19	3	109	69	5.1	0.03	33	521	1047	100

TABLE B2 (continued): *E. nitens* (CV) 15 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
19	Tree	168	69	17.1	0.224	45	464	1022	121
20	1	251	195	6	0.24	63	462	1058	128
20	2	195	159	6	0.15	60	499	1037	108
20	3	159	81	8.6	0.1	40	539	1050	94
20	Tree	251	81	20.6	0.484	59	490	1050	115
21	1	290	218	6	0.31	68	480	1065	122
21	2	218	173	6	0.18	67	499	1033	107
21	3	173	89	8.7	0.12	42	529	1012	91
21	Tree	290	89	20.7	0.608	62	495	1045	111
22	1	248	182	6	0.22	68	453	1072	136
22	2	182	144	6	0.13	62	488	1055	115
22	3	144	62	8.9	0.08	38	513	1049	104
22	Tree	248	62	20.9	0.423	62	474	1063	124
23	1	315	224	6	0.35	63	478	1091	127
23	2	224	170	6	0.18	56	473	1041	119
23	3	170	88	8.5	0.11	36	474	1010	113
23	Tree	315	88	20.5	0.644	55	476	1062	122
24	1	205	167	6	0.16	69	455	1035	127
24	2	167	133	6	0.11	64	478	1009	111
24	3	133	66	8.3	0.07	29	512	1018	98
24	Tree	205	66	20.3	0.337	59	474	1023	116
25	1	269	211	6	0.27	67	420	1006	139
25	2	211	161	6	0.16	63	458	1038	126
25	3	161	86	8.6	0.11	36	454	1020	124
25	Tree	269	86	20.6	0.543	58	438	1018	132
A	1	428	335	6	0.69	61	453	1097	142
A	2	335	277	6	0.44	59	477	1095	129
A	3	277	208	6	0.28	54	518	1100	112
A	4	208	116	6.6	0.14	36	543	1092	100
A	Tree	428	116	24.6	1.551	57	480	1097	129
B	1	269	218	6	0.28	54	445	1029	130
B	2	218	175	6	0.18	56	457	1015	121
B	3	175	134	6	0.11	45	485	1024	111
B	4	134	77	5.9	0.05	20	527	1025	94
B	Tree	269	77	23.9	0.629	49	463	1024	121
Mean	1	259	198	6	0	59	456	1060	132
Mean	2	198	155	6	0	52	480	1039	117
Mean	3	159	99	7	0	34	509	1047	105
Mean	4	156	88	6	0	17	533	1060	98
Mean	Tree	259	77	20	1	51	474	1052	122

TABLE B3: *E. nitens* (NSW) 15 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
5	1	327	241	6	0.38	74	473	1120	136
5	2	241	202	6	0.23	74	467	1046	124
5	3	202	160	6	0.16	63	470	1011	115
5	4	160	91	7.4	0.09	44	511	1077	110
5	Tree	327	91	25.4	0.864	69	475	1076	126
9	1	449	336	6	0.73	66	408	1058	158
9	2	336	300	6	0.48	69	411	1055	156
9	3	300	250	6	0.36	61	438	1067	143
9	4	250	185	6	0.22	55	449	1077	139
9	5	185	94	6	0.09	22	444	1082	143
9	Tree	449	94	30	1.885	62	421	1062	152
13	1	361	239	6	0.43	70	597	1130	94
13	2	239	187	6	0.21	67	467	1114	138
13	3	187	134	6	0.12	58	480	1109	131
13	4	134	81	5	0.05	20	478	1101	130
13	Tree	361	81	23	0.814	64	538	1121	113
14	1	349	243	6	0.42	79	442	1103	149
14	2	243	196	6	0.23	70	407	1052	158
14	3	196	137	6	0.13	62	422	1056	153
14	4	137	79	4.6	0.04	25	500	1066	113
14	Tree	349	79	22.6	0.82	70	432	1079	150
15	1	228	180	6	0.2	50	452	1110	144
15	2	180	142	6	0.12	50	451	1075	138
15	3	142	102	6	0.07	57	487	1061	118
15	4	102	66	4.4	0.02	0	520	1061	103
15	Tree	228	66	22.4	0.415	50	462	1088	135
18	1	249	181	6	0.22	73	477	1105	131
18	2	181	144	6	0.12	67	462	1051	127
18	3	144	84	8.2	0.09	44	495	1043	110
18	Tree	249	84	20.2	0.43	66	476	1077	126
19	1	141	106	6	0.07	43	430	1111	158
19	2	106	69	6	0.04	0	438	1085	148
19	Tree	141	69	12	0.109	28	432	1102	155
23	1	281	225	6	0.3	67	446	1136	155
23	2	225	187	6	0.2	65	440	1093	148
23	3	187	145	6	0.13	54	457	1089	138
23	4	145	83	2	0.02	50	495	1099	122
23	Tree	281	83	20	0.655	64	448	1112	148

TABLE B3 (continued): *E. nitens* (NSW) 15 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
24	1	255	164	6	0.21	57	465	1116	139
24	2	164	129	6	0.1	50	453	1060	134
24	3	129	87	6	0.06	33	483	1040	117
24	Tree	255	87	18	0.367	52	464	1089	134
Mean	1	293	213	6	0	64	466	1110	140
Mean	2	213	173	6	0	57	444	1070	141
Mean	3	186	137	6	0	54	467	1060	128
Mean	4	155	98	5	0	32	492	1080	120
Mean	Tree	293	82	22	1	58	461	1090	138

TABLE B4: *E. Regnans* 15 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
6	1	288	239	6	0.33	21	439	1134	158
6	2	239	210	6	0.24	25	434	1110	154
6	3	210	168	6	0.17	18	433	1089	151
6	4	168	96	9	0.13	8	441	1084	146
6	Tree	288	96	27	0.861	20	437	1111	154
7	1	498	394	6	0.94	62	429	1082	152
7	2	394	341	6	0.64	56	406	1050	158
7	3	341	293	6	0.47	47	417	1058	153
7	4	293	250	6	0.35	34	431	1093	153
7	5	250	104	7.3	0.19	21	437	1111	154
7	Tree	498	104	31.3	2.592	51	422	1073	154
12	1	453	362	6	0.79	63	401	1059	163
12	2	362	324	6	0.55	56	417	1047	151
12	3	324	267	6	0.41	44	422	1040	146
12	4	267	187	6	0.25	32	415	1046	151
12	5	187	101	5.9	0.1	20	426	1073	152
12	Tree	453	101	29.9	2.098	52	412	1051	155
13	1	422	330	6	0.67	66	415	1121	170
13	2	330	286	6	0.45	47	431	1121	160
13	3	286	237	6	0.32	47	434	1102	154
13	4	237	175	6	0.2	45	436	1088	149
13	5	175	97	5.5	0.08	13	443	1094	147
13	Tree	422	97	29.5	1.724	52	426	1113	161
17	1	281	237	6	0.32	28	431	1104	156
17	2	237	193	6	0.22	23	454	1109	143
17	3	193	153	6	0.14	21	461	1097	137
17	4	153	86	8.4	0.1	10	488	1112	127
17	Tree	281	86	26.4	0.774	22	450	1105	145
18	1	316	265	6	0.4	55	442	1106	150
18	2	265	225	6	0.28	32	423	1076	154
18	3	225	181	6	0.19	26	429	1065	147
18	4	181	128	6	0.11	18	443	1067	140
18	5	128	79	4.5	0.04	0	453	1085	139
18	Tree	316	79	28.5	1.029	37	435	1085	149
20	1	203	154	6	0.15	40	423	1101	160
20	2	154	122	4.9	0.07	29	403	1053	161
20	3	122	87	4.8	0.04	0	416	1034	148
20	Tree	203	87	15.7	0.266	34	416	1077	158

TABLE B4 (continued): *E. Regnans* 15 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
21	1	237	186	6	0.21	48	404	1104	172
21	2	186	155	6	0.14	29	407	1084	166
21	3	155	80	9.6	0.11	9	416	1062	155
21	Tree	237	80	21.6	0.457	33	407	1088	166
Mean	1	337	271	6	0	48	423	1101	160
Mean	2	271	232	6	0	37	422	1081	156
Mean	3	232	183	6	0	27	429	1068	149
Mean	4	217	154	7	0	25	442	1082	144
Mean	5	185	95	6	0	14	440	1091	148
Mean	Tree	337	91	26	1	38	426	1088	155

TABLE B5: *E. Fastigata* 15 yr old wood property data.

Tree No.	Log No.	Log LED (mm)	Log SED (mm)	Log Length (mm)	Log Volume (m3)	Heart Volume (%)	Basic Density (kg/m3)	Green Density (kg/m3)	M.C. (%)
4	1	373	230	6	0.44	30	474	1127	137
4	2	230	185	6	0.2	15	399	1143	214
4	3	185	131	6	0.12	17	339	1145	271
4	4	131	82	4.5	0.04	0	490	1112	127
4	Tree	373	82	22.5	0.8	24	436	1133	176
8	1	315	219	6	0.34	53	475	1170	146
8	2	219	177	6	0.19	26	474	1135	139
8	3	177	110	7.8	0.13	23	465	1123	141
8	Tree	315	110	19.8	0.653	40	472	1151	143
12	1	377	261	6	0.48	42	466	1113	138
12	2	261	224	6	0.28	39	458	1084	137
12	3	224	168	6	0.18	39	507	1125	121
12	4	168	90	7.1	0.1	20	502	1127	124
12	Tree	377	90	25.1	1.04	39	474	1108	134
13	1	370	262	6	0.48	33	494	1160	134
13	2	262	210	6	0.26	46	500	1144	128
13	3	210	100	7.5	0.15	27	499	1126	125
13	Tree	370	100	19.5	0.886	37	497	1150	131
14	1	251	175	6	0.22	23	486	1159	138
14	2	175	140	6	0.12	17	476	1086	128
14	3	140	87	5.5	0.01	0	475	1092	130
14	Tree	251	87	17.5	0.339	21	482	1132	135
15	1	223	152	6	0.17	65	482	1142	137
15	2	152	102	8.5	0.11	73	497	1117	124
15	Tree	223	102	14.5	0.277	68	488	1132	132
19	1	345	238	6	0.4	43	459	1100	139
19	2	238	215	6	0.24	50	501	1119	122
19	3	215	161	6	0.17	41	503	1124	123
19	4	161	80	7.3	0.09	22	478	1110	132
19	Tree	345	80	25.3	0.901	42	481	1110	131
21	1	225	166	6	0.18	44	474	1147	143
21	2	166	130	6	0.1	30	525	1143	117
21	3	130	94	5.5	0.05	20	533	1143	114
21	Tree	225	94	17.5	0.34	34	499	1145	130
Mean	1		213	6	0	42	476	1140	139
Mean	2		173	6	0	37	479	1121	139
Mean	3		122	6	0	24	474	1125	146
Mean	4		84	6	0	14	490	1116	128
Mean	Tree		93	20	1	38	479	1133	139

APPENDIX C

PULP QUALITY DATA

TABLE C1: Pulp quality data of 8 year-old *E. nitens* (Central Victoria) cold soda pulp.

Pulp Number	94054	94055	94056	94057	94099	94100	94101	94102	94103	94104	94105	94106
Pulping Conditions												
Presteaming temperature, ^{o}C	80				80				80			
Sodium hydroxide applied, %	7.30				7.78				7.78			
Preheating temperature, ^{o}C	50				50				50			
Residence time, min	20				20				20			
Refiner inlet pressure, bar	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Refiner outlet pressure, bar	1.2	1.5	1.5	1.5	1.2	1.5	1.5	1.5	1.2	1.5	1.5	1.5
Refiner stage	1	2	2	2	1	2	2	2	1	2	2	2
Discharge consistency, %	32.2	29.6	32.5	36.7	29.1	30.0	33.9	37.6	28.8	29.6	30.0	33.3
Feedrate, o.d. kg/min	10.00	9.16	9.73	10.59	9.56	9.55	9.45	8.41	9.63	9.50	8.96	9.07
Energy, kWh/odt	658	443	599	742	791	500	675	935	793	531	706	893
Total energy, kWh/odt		1101	1257	1400		1291	1466	1726		1324	1499	1686
Pulp properties												
Freeness, CSF	397	263	194	180	410	222	185	157	361	211	193	150
Tear index, $mN.m^2/g$		4.8	5.2	5.6		5.0	5.1	5.3		5.4	5.6	5.6
Burst index, $kPa.m^2/g$		2.22	2.35	2.45		2.18	2.34	2.35		2.28	2.6	2.75
Sheet density, kg/m^3		483	496	504		466	483	494		486	495	519
Bulk, cm^3/g		2.07	2.02	1.98		2.15	2.07	2.02		2.06	2.02	1.93
Air resistance, s/100 mL		7	12	14		8	13	14		12	15	22
Tensile index, Nm/g		40.6	42.8	44.7		39.9	40.7	44.3		44.1	45.7	48.4
Stretch, %		1.87	1.63	1.98		1.72	1.67	1.73		2.18	2.16	2.43
Tensile energy index, J/kg		544	475	615		467	453	490		673	686	826
Youngs modulus, MN/m^2		2481	2714	2734		2400	2523	2548		2737	2897	2825
Brightness, %		45.5	46.6	46.7		46.0	46.1	46.0		45.4	45.9	45.7
Scattering coefficient, m^2/a.d. kg		48.6	48.8	48.8		47.7	50.0	50.1		49.3	50.0	49.8
Opacity, %		96.4	96.4	96.9		97.0	97.3	97.8		97.0	97.1	97.1
Bauer McNett, wt % +14	0.2	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.3	0.1	0.0	0.0
+30	1.1	0.4	0.2	0.2	1.7	0.3	0.2	0.2	1.6	0.2	0.1	0.1
+50	19.5	16.9	15.2	13.9	18.4	15.0	13.4	11.9	19.8	15.7	14.9	12.4
+100	41.3	42.0	41.7	42.2	40.2	42.7	42.0	41.8	41.0	42.9	41.9	42.1
+200	20.6	20.9	21.6	21.6	21.6	22.6	22.4	23.1	20.8	22.5	22.3	23.3
-200	17.3	19.8	21.3	22.0	18.1	19.4	21.9	23.0	16.4	18.6	20.8	22.1
L-weighted ave. fibre length, mm	0.68	0.67	0.67	0.65	0.67	0.66	0.66	0.66	0.68	0.66	0.65	0.65
Pulmac shive, %	0.32	0.16	0.08	0.04	0.34	0.04	0.08	0.16	0.24	0.08	0.04	0.04

TABLE C2: Pulp quality data of 15 year-old *E. nitens* (Central Victoria) cold soda pulp.

Pulp Number	94043	94044	94045	94046	94081	94082	94083	94084	94085	94086	94087	94088
Pulping Conditions												
Presteaming temperature, °C	80				80				80			
Sodium hydroxide applied, %	8.85				8.05				8.05			
Preheating temperature, °C	50				50				50			
Residence time, min	20				20				20			
Refiner inlet pressure, bar	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Refiner outlet pressure, bar	1.2	1.5	1.5	1.5	1.2	1.5	1.5	1.5	1.2	1.5	1.5	1.5
Refiner stage	1	2	2	2	1	2	2	2	1	2	2	2
Discharge consistency, %	29.5	27.7	30.6	33.2	33.5	31.1	32.2	39.4	30.2	29.2	33.1	37.0
Feedrate, o.d. kg/min	9.08	9.29	9.88	9.88	9.63	10.33	10.43	10.00	9.57	9.49	9.83	9.51
Energy, kWh/odt	765	429	615	792	773	417	576	801	792	458	596	866
Total energy, kWh/odt		1194	1380	1557		1190	1349	1574		1250	1388	1658
Pulp properties												
Freeness, CSF	430	265	191	172	488	301	251	208	460	273	237	171
Tear index, $mN.m^2/g$		6.8	7.7	7.4		5.8	6.8	7.1		6.1	6.6	7.7
Burst index, $kPa.m^2/g$		2.66	2.88	3.1		1.93	2.29	2.41		2.07	2.46	2.62
Sheet density, kg/m^3		456	482	493		413	441	458		429	447	452
Bulk, cm^3/g		2.19	2.07	2.03		2.42	2.27	2.18		2.33	2.24	2.21
Air resistance, s/100 mL		8	16	20		4	6	12		5	9	13
Tensile index, Nm/g		42.3	48.8	51.4		39.2	42.0	44.9		42.2	43.6	48.3
Stretch, %		2.02	2.41	2.46		1.72	1.93	2.02		2.06	2.12	2.13
Tensile energy index, J/kg		736	829	896		434	557	625		601	644	672
Youngs modulus, MN/m^2		2772	2966	3083		2023	2629	2522		2394	2467	2574
Brightness, %		48.2	49.8	50.1		49.2	48.3	48.8		48.4	50.2	49.9
Scattering coefficient, m^2/a.d. kg		48.1	49.0	49.6		47.6	48.7	50.1		48.4	49.1	51.0
Opacity, %		95.5	95.2	95.3		97.1	96.8	96.7		96.8	96.2	96.8
Bauer McNett, wt % +14	0.2	0.0	0.0	0.0	0.6	0.1	0.1	0.1	0.5	0.0	0.0	0.0
+30	1.4	0.5	0.2	0.1	2.8	1.0	0.4	0.3	2.2	0.4	0.2	0.2
+50	32.7	29.8	28.6	26.1	31.5	28.9	28.0	27.5	31.3	28.0	27.4	26.2
+100	36.4	38.1	38.2	37.8	38.2	38.5	39.5	37.5	37.5	39.1	38.2	39.3
+200	14.2	15.6	15.2	15.7	13.8	14.8	15.6	15.1	14.2	15.5	15.5	15.6
-200	15.2	16.1	17.8	20.3	13.1	16.7	16.5	19.6	14.4	17.0	18.7	18.8
L-weighted ave. fibre length, mm	0.79	0.77	0.77	0.75	0.79	0.76	0.75	0.75	0.79	0.75	0.75	0.74
Pulmac shive, %	0.36	0.32	0.24	0.32	0.68	0.28	0.28	0.40	0.52	0.40	0.28	0.28

TABLE C3: Pulp quality data of 15 year-old *E. nitens* (NSW) cold soda pulp.

Pulp Number		94059	94060	94061	94062	94072	94073	94074	94075	94076	94077	94078	94079
Pulping Conditions													
Presteaming temperature, °C		80				80				80			
Sodium hydroxide applied, %		8.15				8.12				8.12			
Preheating temperature, °C		50				50				50			
Residence time, min		20				20				20			
Refiner inlet pressure, bar		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Refiner outlet pressure, bar		1.2	1.5	1.5	1.5	1.2	1.5	1.5	1.5	1.2	1.5	1.5	1.5
Refiner stage		1	2	2	2	1	2	2	2	1	2	2	2
Discharge consistency, %		30.8	32.5	33.5	39.2	33.9	30.5	34.6	42.0	30.5	30.0	33.8	34.9
Feedrate, o.d. kg/min		9.84	10.62	10.00	9.54	9.26	9.89	10.02	9.11	9.31	9.74	9.74	9.54
Energy, kWh/odt		701	399	582	826	803	488	640	953	790	454	667	863
Total energy, kWh/odt			1100	1283	1527		1291	1443	1756		1244	1457	1653
Pulp properties													
Freeness, CSF		430	310	238	188	394	202	193	137	450	241	213	170
Tear index, mN.m^2/g			7.2	6.9	7.0		7.0	8.0	7.6		7.0	7.6	7.5
Burst index, kPa.m^2/g			2.41	2.6	2.79		2.58	2.74	3.34		2.59	2.55	2.91
Sheet density, kg/m^3			459	493	508		462	493	518		478	474	511
Bulk, cm^3/g			2.18	2.03	1.97		2.16	2.03	1.93		2.09	2.11	1.96
Air resistance, s/100 mL			8	12	17		14	16	36		10	12	22
Tensile index, Nm/g			42.4	45.1	46.1		46.0	47.4	52.1		46.3	44.6	49.8
Stretch, %			2	2.18	2.11		2.2	2.31	2.48		2.3	2.19	2.58
Tensile energy index, J/kg			604	692	682		709	767	915		751	691	912
Youngs modulus, MN/m^2			2622	2700	2709		2728	2865	3338		2806	2834	3107
Brightness, %			47.5	48.2	49.6		48.0	49.6	49.7		48.3	48.3	50.1
Scattering coefficient, m^2/a.d. kg			46.7	47.5	48.1		49.7	49.0	49.9		47.8	49.1	48.6
Opacity, %			95.5	95.8	96.0		97.3	97.2	97.5		97.0	97.0	96.4
Bauer McNett, wt %	+14	0.2	0.1	0.1	0.0	0.4	0.1	0.0	0.1	0.3	0.0	0.0	0.1
	+30	1.9	0.4	0.2	0.3	2.0	0.6	0.3	0.2	2.2	0.6	0.2	0.7
	+50	33.0	32.0	29.7	29.8	33.0	31.3	29.2	29.8	32.1	33.3	29.8	27.6
	+100	35.7	36.6	36.5	36.4	36.2	37.4	37.2	35.9	35.4	36.4	37.6	37.7
	+200	15.1	15.7	15.6	15.7	15.3	14.9	15.3	14.7	18.8	14.4	15.4	16.4
	-200	14.1	15.2	18.0	17.8	13.2	15.7	18.0	19.3	11.3	15.3	17.0	17.6
L-weighted ave. fibre length, mm		0.79	0.77	0.76	0.76	0.79	0.77	0.77	0.76	0.78	0.77	0.76	0.76
Pulmac shive, %		0.68	0.46	0.34	0.22	0.48	0.08	0.28	0.36	1.04	0.40	0.48	0.60

TABLE C4: Pulp quality data of 15 year-old *E. regnans* cold soda pulp.

Pulp Number	94039	94040	94041	94042	94090	94091	94092	94093	94094	94095	94096	94097
Pulping Conditions												
Presteaming temperature, °C	80				80				80			
Sodium hydroxide applied, %	9.51				8.68				8.68			
Preheating temperature, °C	50				50				50			
Residence time, min	20				20				20			
Refiner inlet pressure, bar	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Refiner outlet pressure, bar	1.2	1.5	1.5	1.5	1.2	1.5	1.5	1.5	1.2	1.5	1.5	1.5
Refiner stage	1	2	2	2	1	2	2	2	1	2	2	2
Discharge consistency, %	23.6	25.6	24.8	27.6	29.6	29.3	30.8	35.9	27.5	29.4	28.8	35.8
Feedrate, o.d. kg/min	7.10	8.03	9.97	8.05	8.57	10.53	9.60	9.19	8.56	8.65	8.91	8.66
Energy, kWh/odt	859	427	560	808	846	439	727	870	853	512	641	922
Total energy, kWh/odt		1286	1419	1667		1285	1573	1716		1365	1494	1775
Pulp properties												
Freeness, CSF	416	250	220	136	396	223	178	142	405	217	215	158
Tear index, mN.m²/g		7.1	7.7	7.2		6.7	7.5	7.5		6.8	7.8	7.3
Burst index, kPa.m²/g		2.46	2.6	3		2.36	2.84	2.95		2.99	2.7	3.18
Sheet density, kg/m³		473	489	533		474	505	525		507	489	536
Bulk, cm³/g		2.11	2.04	1.88		2.11	1.98	1.90		1.97	2.04	1.87
Air resistance, s/100 mL		10	11	36		6	18	26		16	16	32
Tensile index, Nm/g		46.6	45.9	51.9		42.1	50.3	51.5		48.1	46.7	53.1
Stretch, %		2.08	1.87	2.26		1.71	2.17	2.16		2.24	2.17	2.51
Tensile energy index, J/kg		676	590	813		489	759	773		764	712	940
Youngs modulus, MN/m²		2925	2829	3314		2621	2985	3088		3026	2878	3342
Brightness, %		46.9	46.8	49.0		46.3	47.7	47.3		46.9	47.6	47.3
Scattering coefficient, m²/a.d. kg		44.5	43.6	44.9		43.4	44.2	44.7		43.8	43.2	46.3
Opacity, %		94.4	94.4	94.7		94.6	94.9	94.5		95.3	95.6	95.3
Bauer McNett, wt % +14	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0
+30	2.9	2.2	1.6	0.8	1.7	0.6	0.3	0.3	0.9	0.2	0.1	0.2
+50	30.5	29.7	27.0	23.8	31.3	29.8	29.0	25.7	31.1	30.2	27.8	26.5
+100	40.6	39.3	41.4	40.9	38.4	41.1	39.9	41.5	39.5	39.9	40.9	40.2
+200	13.6	13.8	14.7	15.2	14.3	13.3	13.7	14.0	14.5	14.6	14.8	14.6
-200	12.2	15.0	15.3	19.3	14.1	15.2	17.1	18.6	14.0	15.0	16.4	18.6
L-weighted ave. fibre length, mm	0.84	0.82	0.82	0.78	0.84	0.83	0.81	0.79	0.84	0.79	0.78	0.78
Pulmac shive, %	0.48	0.32	0.28	0.20	0.48	0.36	0.36	0.40	0.48	0.28	0.36	0.04

TABLE C5: Pulp quality data of 15 year-old *E. fastigata* cold soda pulp.

Pulp Number	94047	94049	94050	94051	94064	94065	94066	94067	94068	94069	94070	94079
Pulping Conditions												
Presteaming temperature, ^oC	80				80							
Sodium hydroxide applied, %	8.18				8.28							
Preheating temperature, ^oC	50				50							
Residence time, min	20				20							
Refiner inlet pressure, bar	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Refiner outlet pressure, bar	1.2	1.5	1.5	1.5	1.2	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Refiner stage	1	2	2	2	1	2	2	2	2	2	2	2
Discharge consistency, %	31.5	32.1	35.1	40.2	25.3	27.2	29.8	36.4	28.3	30.9	32.8	34.9
Feedrate, o.d. kg/min	9.43	10.50	9.87	10.10	8.34	8.96	8.60	8.10	8.39	8.35	8.24	9.54
Energy, kWh/odt	715	442	607	779	849	500	647	963	508	720	987	863
Total energy, kWh/odt		1157	1322	1494		1349	1496	1812	1357	1569	1836	1653
Pulp properties												
Freeness, CSF	545	345	271	219	502	308	209	182	262	220	187	170
Tear index, $mN.m^2/g$			5.3	5.4		5.2	5.6	5.6	5.2	5.8	5.9	7.5
Burst index, $kPa.m^2/g$			1.85	2.19		1.97	2.16	2.67	2.04	2.35	2.28	2.91
Sheet density, kg/m^3			436	445		422	453	479	442	454	467	511
Bulk, cm^3/g			2.29	2.25		2.37	2.21	2.09	2.26	2.20	2.14	1.96
Air resistance, s/100 mL			4	6		4	8	12	4	8	9	22
Tensile index, Nm/g			36.7	39.9		35.4	39.8	44.8	38.3	40.3	41.5	49.8
Stretch, %			1.58	1.89		1.39	1.68	2.02	1.72	1.79	1.8	2.58
Tensile energy index, J/kg			389	522		324	453	627	446	491	508	912
Youngs modulus, MN/m^2			2215	2498		2280	2280	2545	2193	2292	2428	3107
Brightness, %			50.9	50.7		48.7	51.3	50.7	50.0	50.5	50.9	50.1
Scattering coefficient, m^2/a.d. kg			47.0	48.3		45.4	47.1	48.9	45.3	47.9	46.2	48.6
Opacity, %			95.1	95.7		94.9	94.6	94.9	94.6	95.2	94.9	96.4
Bauer McNett, wt % +14	0.5	0.1	0.1	0.0	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.1
+30	1.6	0.3	0.2	C.1	1.6	0.4	0.0	0.0	0.1	0.1	0.2	0.7
+50	27.4	24.9	22.6	22.2	27.5	22.7	23.4	21.4	23.9	23.4	22.8	27.6
+100	41.9	44.3	44.1	43.8	41.3	44.6	42.1	42.4	43.8	42.4	43.0	37.7
+200	14.2	15.2	15.9	15.4	14.8	15.5	15.2	15.1	15.6	15.4	15.4	16.4
-200	14.5	15.2	17.2	18.5	14.5	16.7	19.3	21.1	16.6	18.8	18.7	17.6
L-weighted ave. fibre length, mm	0.76	0.75	0.74	0.74	0.76	0.73	0.74	0.74	0.74	0.74	0.74	0.76
Pulmac shive, %	0.76	0.48	0.48	0.20	0.64	0.64	0.44	0.40	0.40	0.20	0.18	0.60