KRAFT FIBRE QUALITIES OF *PINUS RADIATA* TOPLOGS, THINNINGS, AND SLABWOOD, AND A "GENETIC MISFIT"*

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ABSTRACT

Kraft fibre, pulp, and handsheet properties for 11 standard *Pinus radiata* D. Don wood samples were compared with four corresponding samples of the progeny of Clone 850-55 (C55). The standard samples included 9-, 12-, 15-, and 18-year-old toplog and thinnings, and three slabwood samples. Two toplog and two slabwood C55 wood samples were included in the comparison.

It is generally accepted that the basic density of standard New Zealand *P. radiata* wood chips is strongly correlated with pulp coarseness and handsheet properties. For the C55-toplog pulps such relationships held for handsheet properties but not for pulp fibre coarseness. For the C55-slabwood pulps the converse occurred since standard slabwood and C55-slabwood pulp coarseness and handsheet properties were similar but chip basic densities were very different.

C55 kraft fibres, at a given pulp coarseness or fibre wall area, are proportionately large (broad) and thin walled compared with standard *P. radiata* kraft fibres. Thus, C55 fibres can be expected to collapse and bond readily one to another and develop high sheet tensile strengths and densities with minimal refining. The handsheet properties obtained supported such interpretations for the C55-toplog pulps, but not necessarily for the coarse long-fibred C55-slabwood pulps. The kraft pulp and fibre properties of the progeny of Clone 850-55 were so unusual that they evoke the question "Is this clone a genetic misfit?"

Fibre cross-section dimensions correlated with pulp coarseness more strongly for dried and rewetted pulps than for undried (never dried) pulps. Fibre wall substance densities and porosities are apparently more variable in undried pulps than in dried and rewetted pulps.

Keywords: kraft pulp; handsheets; fibres; thinnings; toplogs; slabwood; *Pinus radiata.*

INTRODUCTION

The basic density of New Zealand *Pinus radiata* wood chips has been shown previously to be strongly correlated with tree age, position within a tree, and growing site, and with pulp

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coarseness and handsheet properties. In fact, many kraft fibre and pulp properties are predictable from chip basic density alone (Kibblewhite 1985). More recently, it has been found for pulps from thinnings that some abrupt changes in *P. radiata* kraft fibre qualities can occur at chip basic densities below about 350–360 kg/m^3, resulting in some selective changes in their papermaking qualities (Kibblewhite & Bawden 1991).

The fibre and handsheet qualities of kraft pulps prepared from wood of half-sib progeny of Clone 850-55 (one common parent 55, and several other parents) (C55), which showed relatively low basic density, have been characterised as part of an on-going programme of monitoring kraft and mechanical pulp qualities of a wide range of *P. radiata* wood types. Previous research has shown that the C55 wood type produces mechanical pulps with very desirable refining energy requirements, and with good pulp and handsheet properties (Corson *et al.* 1989). Also, a study of the physical and chemical properties of C55 and standard *P. radiata* wood has recently been completed by Nyakuengama (1991). Based on an extensive study of wood discs and sections, Nyakuengama found that the C55 material contained "mild" compression wood with fibres which were on average larger and thinner walled than those in the standard *P. radiata* wood sample. In the study described here, toplog and slabwood C55 kraft pulp and fibre qualities were compared with those of two slabwood samples from different wood types, and those of the eight thinnings and toplog samples of different age described elsewhere (Kibblewhite & Bawden 1991). The kraft pulps were each prepared from well-mixed commercial-size chip samples made up from large numbers of trees (Kibblewhite & Bawden 1991; Corson *et al.* 1989).

METHODS

Sample Selection and Preparation

The 9-, 12-, 15-, and 18-year-old whole-tree thinnings, and the 38-year-old trees from which the toplog and slabwood material was taken were grown on sites of roughly equivalent site index and given very similar silvicultural treatments. Chips from some 60 to 90 trees were included in each bulked sample. Further details of the toplog and thinnings samples and pulps are presented elsewhere (Kibblewhite & Bawden 1991).

Thirty-one 22-year-old trees were selected from five full-sib families of Clone 850-55 for mechanical pulping trials. These were located in Compartment 1350 Kaingaroa Forest, and included the following families: 121×55 (seven trees), 99×55 (nine trees), 97×55 (five trees), 88×55 (five trees), and 80×55 (five trees)—all parent clones prefixed 850. The bulked C55-toplog chip sample was of basic density 350 kg/m^3, extractive content 1.46%, and lignin content 28.2%. For the C55-slabwood sample corresponding values were 375 kg/m^3, 0.84%, and 27.6%. The toplog sample consisted of roundwood which contained as few as five and as many as 14 annual growth layers from the pith. The slabwood sample contained material from outside the fifteenth growth layer.

The 1060 and 1013 slabwood samples were prepared from 33- and 26-year-old trees respectively from Compartments 1060 and 1013 in Kaingaroa Forest, and consisted of wood material from outside the fifteenth growth layer.

Toplog and slabwood samples were chipped in a commercial chipper. Chip samples labelled unscreened passed through a 40-mm overs screen and were retained on a 10-mm screen. C55 chips which subsequently passed through a 26-mm screen and were retained on a 13-mm screen of a round-hole Williams chip classifier were labelled screened.

Pulping and Pulp Processing

Kraft pulps of Kappa number 28-30 were prepared from screened and unscreened C55-toplog and C55-slabwood, and the screened 1013 and 1060 slabwood samples, by pulping 200 g o.d. chips using a 15% effective alkali charge. Similar pulping conditions were used to produce the toplog and thinnings pulps (Kibblewhite & Bawden 1991). Further details of pulping procedures can be made available on request (unpubl. data). Handsheets were prepared and pulp physical evaluations made in accordance with APPITA standard procedures. The load applied during pulp refining with the PFI mill was 3.4 N/mm. Pulps were refined at 10% stock concentration. Handsheet physical evaluation data are reported on o.d. bases.

Fibre Dimension Measurement

Relative weighted average fibre length and fibre coarseness were determined using a Kajaani FS-200 instrument and standard PAPRO (Pulp and Paper Research Organisation of New Zealand) procedures. Cross-section fibre dimensions of thickness, width, wall area, and wall thickness were measured using image processing procedures described previously (Kibblewhite & Bailey 1988).

The fibre parameters of width, thickness, and wall area were as indicated in Fig. 1 for undried and for dried and rewetted fibres. The product fibre width × fibre thickness represents the minimum fibre cross-section rectangle. Also, fibre cross-section wall area is equivalent to fibre wall volume per unit length. The ratio width:thickness can give an indication of fibre collapse since the greater the width and the lower the thickness of a fibre cross-section, the greater is the extent of fibre collapse.

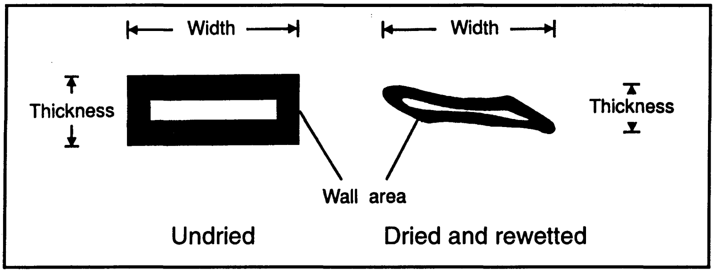

FIG. 1–Schematic diagram of fibre cross-section dimensions for undried, and dried and rewetted fibres

RESULTS

Pulp and Fibre Properties

Clone 55 progeny (C55) and the thinnings, toplog, and slabwood (standard) pulps had very different chip density/pulp coarseness relationships (Fig. 2; Table 1). For given chip basic densities, the C55 pulps had very high coarseness compared with those of the corresponding standard *P. radiata* pulps. Also, with chip basic density as the basis of comparison, length weighted fibre lengths were greater for the C55 than for the standard

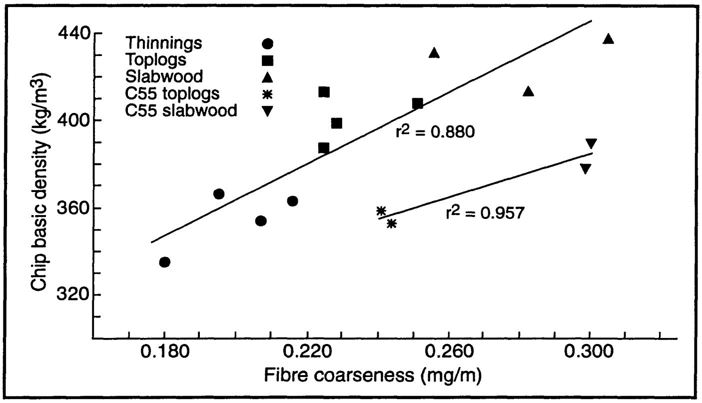

FIG. 2–Chip basic density and pulp fibre coarseness

TABLE 1–Chip basic density and pulp fibre length and coarseness

Wood origin	Chip basic density (kg/m^3)	FS 200 fibre length (mm)	FS 200 fibre coarseness (mg/m)
Thinnings-9 yr	335	1.97	0.180
Thinnings-12 yr	367	2.02	0.195
Thinnings-15 yr	354	2.26	0.207
Thinnings-18 yr	364	2.40	0.216
C55-toplog	358	2.47	0.241
C55-toplog	353	2.48	0.244
Toplogs-9 yr	388	2.56	0.225
Toplogs-12 yr	399	2.45	0.228
Toplogs-15 yr	413	2.58	0.225
Toplogs-18 yr	408	2.71	0.251
Slabwood	431	2.88	0.256
Slabwood-1060	438	2.93	0.305
Slabwood-1013	414	2.84	0.282
C55-slabwood	390	3.13	0.300
C55-slabwood	379	3.09	0.299

pulps (Table 1). In contrast, length-weighted fibre lengths were strongly correlated (r^2 = 0.948) with fibre coarseness, with the C55-slabwood furnish having both the longest and coarsest fibres (Table 1).

Fibre cross-section dimensions and selected dimension ratios are noted in Table 2 for undried pulps and in Table 3 for pulps reconstituted from dried handsheets. For the undried pulps the fibre wall area/coarseness relationship was poor for the standard pulps (r^2 = 0.345) and very different from that of the C55 pulps (r^2 = 0.956). Fibre wall areas for the dried pulps, on the other hand, were strongly correlated with coarseness (r^2= 0.709), with the C55 and standard pulps fitting the same regression (Fig. 3). Furthermore, fibre wall area and width × thickness product relationships for the standard and C55 pulps were different for the undried pulps and together for the dried pulps, and with all the data of each of the regressions strongly correlated one to another (Fig. 4).

TABLE 2–Mean fibre cross-section dimensions of undried *Pinus radiata* kraft pulps of very different fibre quality

Wood origin	Fibre width (μm)	Fibre thickness (μm)	Width × thickness (μm^2)	Wall area (μm^2)	(Width × thickness)/ (wall area)	Wall thickness (μm)	(Width × thickness)/ (wall thickness) (μm)	Width/ thickness
Thinnings–9 yr	28.0	15.7	472	229	2.03	3.35	137	1.84
Thinnings–12 yr	29.8	18.4	568	268	2.10	3.71	153	1.67
Thinnings–15 yr	29.7	17.8	547	255	2.14	3.61	153	1.75
Thinnings–18 yr	30.5	17.1	537	267	1.99	3.72	144	1.91
C55–toplog	33.1	17.2	583	269	2.15	3.56	166	2.05
C55–toplog	32.9	17.6	600	267	2.23	3.51	174	1.99
Toplogs–9 yr	30.8	19.1	618	309	1.96	4.05	148	1.71
Toplogs–12 yr	30.9	19.0	605	315	1.90	4.29	140	1.69
Toplogs–15 yr	31.8	20.7	694	350	1.95	4.28	158	1.58
Toplogs–18 yr	31.4	20.8	675	340	1.98	4.44	153	1.58
Slabwood	30.0	20.4	628	334	1.88	4.56	138	1.53
Slabwood–Cpt 1060	30.3	19.2	604	300	1.99	4.19	144	1.64
Slabwood–Cpt 1013	32.1	19.4	640	316	2.00	4.20	153	1.77
C-55 slabwood	33.2	21.1	721	310	2.31	3.92	190	1.67
C-55 slabwood	33.1	20.5	700	323	2.16	4.08	174	1.71
LSD*	1.8	1.1	57	25	0.08	0.21	13	0.12

TABLE 3–Mean fibre cross-section dimensions of *Pinus radiata* dried and rewetted kraft pulps of very different fibre quality

Wood origin	Fibre width (μm)	Fibre thickness (μm)	Width × thickness (μm^2)	Wall area (μm^2)	(Width × thickness)/ (wall area)	Wall thickness (μm)	(Width × thickness)/ (wall thickness) (μm)	Width/ thickness
Thinnings–9 yr	28.0	10.3	289	155	1.83	2.73	107	3.00
Thinnings–12 yr	30.2	10.8	329	178	1.82	2.80	117	3.04
Thinnings–15 yr	30.6	10.7	333	174	1.88	2.71	124	3.12
Thinnings–18 yr	31.7	11.4	369	191	1.90	2.85	129	3.03
C55–toplog	32.3	10.0	324	173	1.86	2.56	129	3.47
C55–toplog	33.1	10.7	356	191	1.85	2.70	133	3.35
Toplogs–9 yr	30.6	11.2	350	187	1.85	2.92	120	2.92
Toplogs–12 yr	28.6	11.6	340	183	1.84	3.03	115	2.61
Toplogs–15 yr	32.6	11.5	380	207	1.83	3.00	127	3.03
Toplogs–18 yr	31.0	12.3	388	209	1.84	3.27	121	2.66
Slabwood	29.7	11.5	345	192	1.79	3.11	113	2.79
Slabwood–Cpt 1060	30.7	12.4	386	212	1.81	3.29	121	2.62
Slabwood–Cpt 1013	30.8	11.9	370	202	1.83	3.10	120	2.75
C-55 slabwood	33.4	12.9	428	228	1.87	3.21	137	2.90
C-55 slabwood	34.1	13.0	444	241	1.83	3.37	134	2.84
LSD*	1.8	0.7	31	15	0.06	0.17	10	0.24

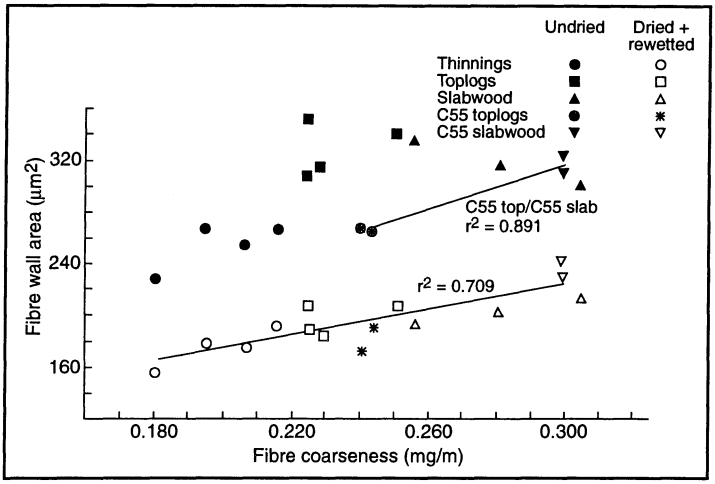

FIG. 3–Fibre wall area and pulp fibre coarseness

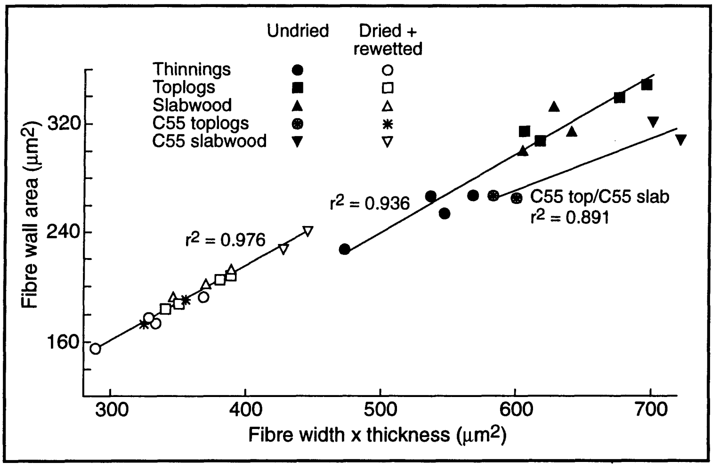

FIG. 4–Fibre wall area and width × thickness product relationships, based on mean values for each pulp.

To simplify the presentation of results, mean fibre quality data have been grouped into slabwood, C55-toplogs and C55-slabwood, toplogs, and thinnings (9 years and 12–18 years) categories (Tables 4–6). The toplog and thinnings groupings are based on previously reported trends for these pulps (Kibblewhite & Bawden 1991). Relationships are most clearly evident through analyses of Table 6 for fibres which had been collapsed or partly collapsed, and for fibre walls which had been contracted and densified, after handsheet making and drying (Kibblewhite 1989). The fibres of the C55-slabwood pulps were exceptionally large or broad with high width × thickness products, and coarse with high wall areas. Width × thickness:wall area ratios (W × T:WA) were, however, the same for all the pulp groupings and hence fibre size/wall volume proportions can be considered to be the same for all the *P. radiata* furnishes. The C55 pulps differed from the standard pulps only in that they contained proportionately more coarse and broad fibres, some of which were

TABLE 4–Wood chip basic density and FS 200 fibre length and coarseness

	Thinnings (9 yr)		Thinnings (12–18 yr)		C55-toplogs		Toplogs (9–18 yr)		Slabwood		C55-slabwood
Chip basic density (kg/m^3)	335	<	362	=	356	<	402	<	428	>>	385
Weighted by length fibre length (mm)	1.97	<	2.33	<	2.48	<	2.55	<	2.88	<	3.11
Fibre coarseness (mg/m)	0.180	<	0.206	<	0.243	>/=	0.232	<	0.281	<	0.300

TABLE 5–Fibre cross-section dimensions of undried pulps

	Thinnings (9 yr)		Thinnings (12–18 yr)		C55-toplogs		Toplogs (9–18 yr)		Slabwood		C55-slabwood
Fibre cross section area (W×T) (µm^2)	472	<	551	=/<	592	<	648	=	634	<<	711
Fibre wall area (WA) (µm^2)	229	<	263	=	268	<	328	=	317	=	316
W×T:WA*	2.03	=	2.08	<	2.19	>	1.95	>	1.62	<<	2.24
Fibre wall thickness (WT) (µm)	3.35	<	3.68	=	3.54	<	4.27	=	4.32	<	4.00
W×T:WT (µm)*	137	<	150	<	170	=	166	>	141	<	182

* Note: W×T:WA and W×T:WT values for the C55toplogs and C55slabwood pulps are higher than those of all other samples and not different one from another based on LSD values (Kibblewhite 1989)

TABLE 6–Fibre cross-section dimensions of pulps prepared from dried and rewetted handsheets

	Thinnings (9 yr)		Thinnings (12–18 yr)		C55-toplogs		Toplogs (9–18 yr)		Slabwood		C55-slabwood
Fibre cross-section area (W×T) (µm^2)	289	<	343	=	340	=/<	365	=	367	<<	436
Fibre wall area (WA) (µm^2)	155	<	183	=	182	<	197	=	202	<	235
W×T:WA	1.83	=	1.87	=	1.86	=	1.83	=	1.81	=	1.85
Fibre wall thickness (WT) (µm)	2.73	=	2.79	=	2.63	<	3.07	=/<	3.17	=/<	3.29
W×T:WT (µm)*	107	<	123	=	131	>	121	=	118	<	136
Fibre width / thickness (W:T)	3.00	=	3.06	<	3.41	>>	2.81	=	2.72	=	2.87

* Note: W×T:WT values for the C55toplogs and C55slabwood pulps are higher than those of all other samples and not different one from another based on LSD values (Kibblewhite 1989)

larger (Fig. 4–6). Compared with the relatively high wall area and coarseness values of the broad C55 fibres, wall thicknesses were proportionately smaller and this is reflected in high fibre size:wall thickness (W × T:WT) and fibre width:thickness (W:T) ratios.

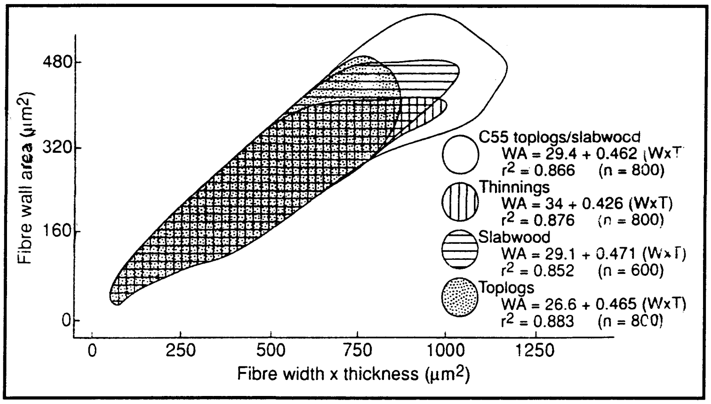

FIG. 5–Fibre population wall area and width × thickness product relationships and variabilities, based on individual fibre values for each pulp

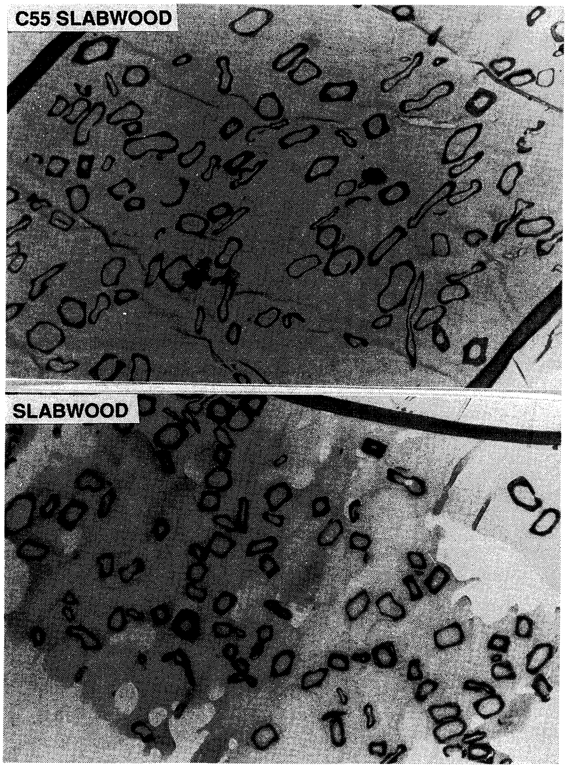

FIG. 6–Slabwood and C55 fibre cross-sections.

Trends for the W × T:WA ratio of the undried and dried pulp groupings are very different (Tables 5 and 6). For the undried C55 pulps, W × T:WA values were higher than those of the standard pulps whereas corresponding values for the dried fibres were the same for all pulps. Such trends suggest that wall substance densities of the C55 undried fibres may be somewhat higher than those of corresponding standard pulps. For a given coarseness, the wall areas of the C55 pulps were less than those of the standard pulps (Fig. 3). Also shown in Fig. 3 is the high wall area/coarseness variability of, in particular, the undried standard slabwood pulps. Much of this variability could also be related to different never-dried wall substance densities (Fig. 3). Variation in wall substance density can be expected to be minimised when fibre walls are contracted through drying (Kibblewhite 1989). The validity of such a statement is at least partly confirmed by the fibre cross-section dimensions obtained from the pulp series reconstituted from handsheets (Table 6).

Handsheet Relationships

Handsheet physical evaluation data for the slabwood and C55 pulps are listed in Table 7. Corresponding data for the toplog and thinnings pulps have been presented elsewhere (Kibblewhite & Bawden 1991). Handsheet tensile/apparent density, tear/tensile, and light-scattering coefficient/apparent density relationships are presented in Fig. 7–9. Slabwood and C55 data are superimposed on to simplified versions of the toplog and thinnings curves presented elsewhere (Kibblewhite & Bawden 1991).

C55-toplogs, C55-slabwood, slabwood, 18-year-old thinnings, and toplog tensile/apparent density regressions can be considered to be generally the same except for individual value magnitudes (Fig. 7). The C55-toplog pulps had exceptionally high tensile strengths but at high apparent densities.

Tear/tensile relationships for the slabwood and C55 slabwood pulps fit roughly the same curve (Fig. 8). Tear/tensile values for the C55-toplog pulps were highly variable.

Optical properties as indicated by light-scattering coefficient/apparent density relationships put the slabwood and C55-slabwood at roughly the same level as 18-year-old toplogs (Fig. 9) (Kibblewhite & Bawden 1991). For the C55-toplog pulps, light-scattering coefficient values were at very high sheet densities and roughly equivalent to those of 15-year-old thinnings.

DISCUSSION

Chip Basic Density, Pulp Coarseness, and Fibre Interrelationships

The basic density of New Zealand *P. radiata* wood chips is strongly correlated with pulp coarseness and handsheet properties. In fact, many kraft fibre and pulp properties are predictable from chip basic density alone (Kibblewhite 1985; Kibblewhite & Bawden 1991). For the C55-toplog pulps, such chip basic density relationships generally held for handsheet properties but not for pulp fibre coarseness (Table 4; Fig. 2, 7–9). For the C55-slabwood pulps the converse held since standard slabwood and C55-slabwood pulp coarseness and handsheet properties were similar and chip basic densities very different.

Both the thinnings and C55-toplogs had chip basic densities equivalent to or below a so-called critical value of about 360 kg/m^3 (Kibblewhite & Bawden 1991). The thinnings pulps

TABLE 7–Handsheet physical evaluation data

Sample	PFI mill rev	Freeness (Csf)	Tear index (mN.m^2/g)	Burst index (kPa.m^2/g)	Apparent density (kg/m^3)	Air resistance (s/100 ml)	Tensile index (N.m/g)	Stretch (%)	T.E.A. (J/m^2)	Young's modulus (MN/m^2)	Scattering coefficient (m^2/kg)
C55-toplogs screened	1000	708	12.5	7.0	712	21	101	2.92	120	6992	17.9
	2000	682	8.9	7.8	741	34	103	3.01	125	7298	15.3
	4000	591	9.2	8.7	771	54	118	3.21	151	8174	12.6
	8000	377	11.5	9.1	791	1098	123	3.36	165	8443	10.5
C55-toplogs unscreened	1000	705	11.9	7.1	719	21	100	3.00	122	7037	18.0
	2000	669	13.5	8.0	746	44	111	3.10	138	7846	15.0
	4000	584	8.4	8.7	764	94	116	3.17	148	8047	12.5
	8000	351	12.0	8.6	794	1010	121	3.08	151	8914	10.3
C55-slabwood screened	1000	735	14.2	5.8	645	3	83	2.66	90	5879	18.2
	2000	714	12.5	7.2	677	5	98	2.86	113	6552	15.2
	4000	662	10.7	7.9	707	12	105	3.02	126	6929	13.3
	8000	447	9.4	8.8	740	74	112	3.23	143	7478	11.1
C55-slabwood unscreened	1000	734	17.0	5.9	636	3	84	2.61	89	5538	17.1
	2000	721	13.0	6.8	666	5	97	2.72	106	6632	15.9
	4000	661	10.8	7.7	705	12	108	3.02	130	7151	13.4
	8000	459	11.0	8.4	733	50	111	3.14	139	7383	11.6
Slabwood 1060	500	744	27.6	3.7	576	1	60	2.00	50	4891	20.1
	1000	741	20.0	5.2	613	1	76	2.18	68	5820	18.5
	2000	733	16.1	6.3	644	1	85	2.57	90	6311	16.2
	4000	673	13.7	7.5	679	3	97	2.79	110	6468	14.0
	8000	417	11.5	8.2	718	45	107	3.07	131	7095	12.2
Slabwood 1013	500	744	19.0	4.9	612	1	69	2.35	67	5127	19.0
	1000	743	16.6	5.6	642	1	81	2.70	90	5584	17.6
	2000	718	13.8	6.7	672	2	87	2.51	88	6126	15.6
	4000	648	11.2	7.8	705	6	100	3.07	125	6773	13.2
	8000	404	10.8	9.1	732	98	110	3.16	141	7428	11.5

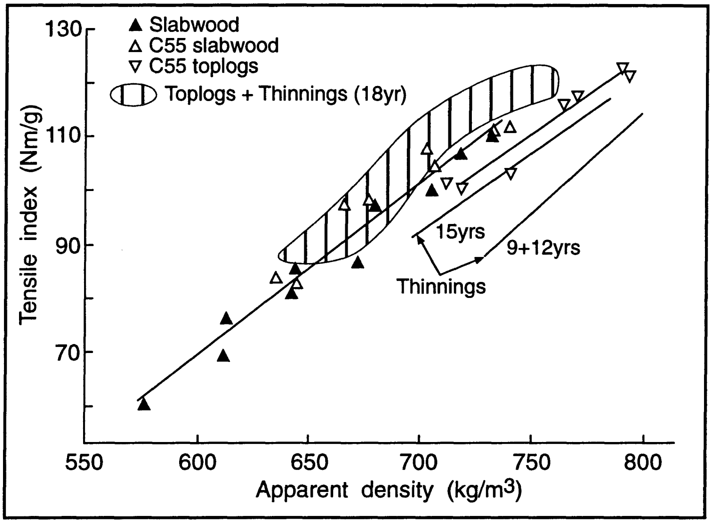

FIG. 7–Handsheet tensile index and apparent density

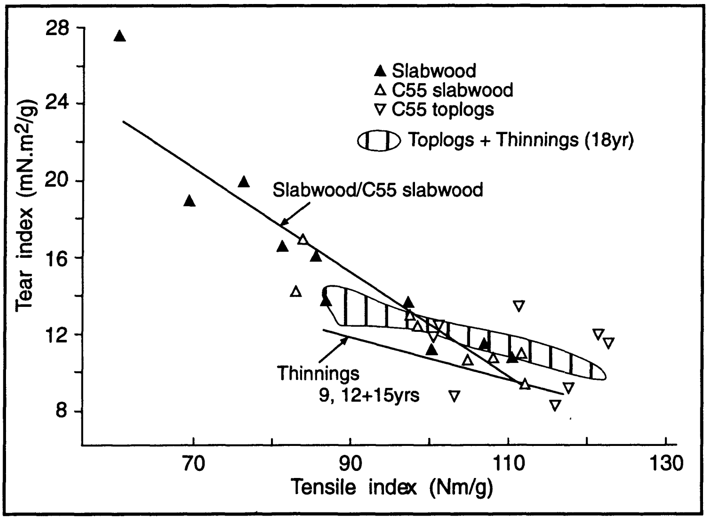

FIG. 8–Handsheet tear index and tensile index

gave extremely high sheet densities at relatively low tensile strengths, apparently because of the short length of their fibres (Kibblewhite & Bawden 1991). The C55-toplog pulps, on the other hand, also gave handsheets with extremely high sheet densities but at somewhat higher tensile strengths. The C55-toplog fibres were readily collapsed and had high bonding potentials, but were long compared with the thinnings fibres (Table 4; Fig. 7–9).

C55-slabwood fibres are of high coarseness but can be expected to be readily collapsed and of high bonding potential because they are very large with proportionately thin walls compared with standard *P. radiata* fibres (Tables 4 and 6). Such a high collapse potential of

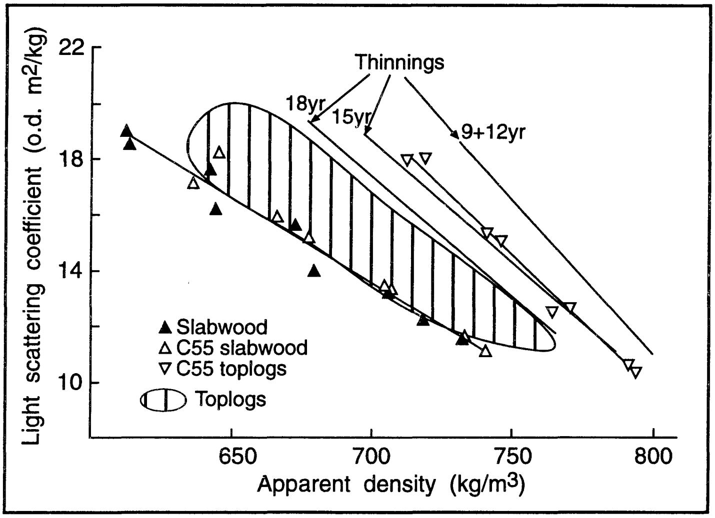

FIG. 9–Handsheet light-scattering coefficient and apparent density

the C55-slabwood pulps is not particularly evident since refining requirements and handsheet properties are almost identical to those of the standard *P. radiata* slabwood pulps (Table 7). The fact that the C55-slabwood pulps fit the slabwood tear/tensile regression is in agreement with high coarseness and long fibres (Fig. 8; Table 4).

Pinus radiata Standard and C55 Fibre Property Interrelationships

The fibre properties of the dried and rewetted C55 and standard *P. radiata* pulps were strongly correlated one to another. Fibre property relationships for coarseness, wall area, cross-section area (width × thickness product) and length were the same for both pulp types, although the C55-slabwood furnishes had the coarsest, longest, and broadest fibres (Fig. 3–5; Tables 4–6).

C55 fibres differed from standard *P. radiata* fibres in that they had abnormally large cross-section areas with proportionately thin walls. The high W × T:WT values of the C55 pulps supported such a conclusion (Table 6). The low C55 chip basic densities at given pulp coarseness values were also explained by the W × T:WT ratio. Compared with standard *P. radiata* wood chips, C55 chips contained large and thin-walled tracheids which were fewer in number and had proportionately larger lumens. Thus, C55 chip basic densities were low but gave kraft pulps with large (broad), thin-walled fibres at normal *P. radiata* pulp coarseness values.

C55 kraft fibres, at a given pulp coarseness or fibre wall area, were proportionately large (broad) and thin-walled as indicated by the ratio W × T:WT (Table 6). Thus, C55 fibres can be expected to collapse and bond readily one to another and develop high sheet tensile strengths and densities with minimal refining. Collapsed, broad, and thin-walled C55 fibres can be expected to behave as wide ribbons within paper structures. Refining requirements (PFI mill rev.) and handsheet properties listed in Table 7 support such interpretations for the C55-toplog pulps but not necessarily for the coarse, long-fibred, C55-slabwood pulps.

All the kraft fibre measurement data confirm trends indicated through the detailed wood disc analyses of C55 and standard *P. radiata* samples carried out by Nyakuengama (1991). The C55 kraft fibres were consistently larger and thinner-walled than those in the standard *P. radiata* pulps.

Undried, and Dried and Rewetted Fibre Property Interrelations

The high variability of fibre wall area/coarseness values for never-dried pulp compared with the strongly correlated data of dried and rewetted pulps requires explanation (Fig. 3). Fibre wall areas can be expected to vary depending on wall structural organisations and the presence or absence of in-built stresses in fibre walls when in wood chips, and how these respond throughout the kraft pulping process (Kibblewhite 1989). Such differences between fibre sources can be expected to be most evident in undried fibres. Variability in fibre wall porosity and density must be minimised as fibre walls are contracted, densified, and bonded as a result of pulp drying processes (Kibblewhite 1989).

For the undried C55 pulps W × T:WA values were significantly and consistently greater than those of the standard pulps (Table 5). This suggests that undried C55 fibre walls are more dense and contain more wall substance per unit area (volume per unit length) than undried standard fibres, when compared at the same coarseness (Fig. 3; Tables 4 and 5). Such an interpretation is supported by the observation that C55 fibres were not contracted by drying to the same extent as the standard *P. radiata* pulps (Tables 4–6).

Pulp Refining and Handsheet Properties

Handsheet properties and refining requirements (PFI mill rev.) of the undried C55-slabwood pulps generally followed those of the standard slabwood *P. radiata* pulps (Table 7). For the C55-toplog pulps, on the other hand, refining requirements to reach given sheet tensile strengths and densities were very low (Table 7) (Kibblewhite & Bawden 1991). In fact, the rapid development of exceptionally high C55-toplog tensile strengths and sheet densities with minimal refining could be a problem in the manufacture of many paper grades (Fig. 7). Reinforcement properties of the C55-toplog pulps were generally low (Fig. 8). For an integrated mill the extreme bonding potentials of the never-dried C55-toplog pulps may require modification of conventional papermaking practices to enable them to be effectively used in the manufacture of many paper grades. As market kraft pulp, on the other hand, the bonding potential and ease of refining of C55-toplog pulps could be a real plus for a papermaker, particularly when in admixture with C55-slabwood pulps or as a component in C55 whole-tree pulps. The pulp drying process causes fibres to become collapsed or partly collapsed and their walls to be contracted and densified, and sheet tensile and densities to decrease (Kibblewhite 1989). Thus the user of C55-toplog and C55 whole-tree market kraft pulps could have pulp which is easier to refine than standard *P. radiata* pulps. Such a possibility would need to be verified since C55 pulps could also be expected to dry, and the fibres to collapse, more easily during drying processes.

CONCLUSIONS

Chip basic densities of C55-toplog pulps are generally indicative of kraft pulp handsheet properties but not of pulp fibre coarseness. For C55 slabwood pulps the converse holds since standard slabwood and C55-slabwood pulp coarseness and handsheet properties were similar and chip basic densities very different.

C55 pulp coarseness values correlate with fibre cross-section wall areas and volumes but give no indication of fibre size and wall thickness, nor of fibre collapse and bonding potential. The C55 fibres at given pulp coarseness values are large and broad with proportionately thin walls, and are easily collapsed and bondable compared with standard *P. radiata* kraft fibres.

Fibre cross-section dimensions correlate with pulp coarseness more strongly for dried and rewetted pulps than for undried (never-dried) pulps. Fibre wall areas and cross-section areas can vary greatly with kraft pulping depending on in-built stresses which exist in fibre walls in wood chips prior to pulping. The release of such stresses with kraft pulping can apparently result in different wall substance densities in undried *P. radiata* fibres of different origin and/or type. Such differences are minimised and/or eliminated during pulp drying processes.

Handsheet properties and refining requirements of the undried C55-slabwood pulps follow those of standard *P. radiata* slabwood pulps of equivalent pulp coarseness. In contrast, C55-toplog pulp refining requirements are low, and handsheet tensile strengths and densities are high. The C55-toplog pulps have properties which are similar to those of 12- to 15-year-old thinnings pulps and very different from those of standard *P. radiata* toplog or corewood pulps.

Despite the intensive research carried out on the offspring of Clone 850-55, no other progenies or clones of *P. radiata* have yet been investigated for their kraft pulp properties. The kraft pulp qualities of the C55 progeny can, therefore, be compared only with *P. radiata* population samples from other sites.

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