The qualities of radiata pine papermaking fibres

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SUMMARY

The types of qualities of fibres available from radiata pine wood are discussed in the context of their properties and those of the pulps and papers produced from them. The characteristics and papermaking qualities of corewood and slabwood, earlywood and latewood, and compression wood fibres are summarized. The major portion of the discussion is concerned with radiata pine fibres in relation to kraft furnishes and a range of mechanical pulps.

In radiata pine we have a very diverse and valuable wood resource containing a wide range of fibre types which can be segregated before and/or during processing. Thus the various types of fibre can be preselected so that the most suitable raw material can be used in the manufacture of quality paper and paperboard products.

Radiata pine trees contain a central core of low density wood (corewood) with tracheids which are short and thin walled compared with those in outerwood or slabwood material(1). Somewhat variable transition zones with indeterminate boundaries exist between corewood and slabwood. Within radiata pine stems, wood densities and tracheid lengths increase with increasing numbers of growth layers from the pith although the magnitude of these changes progressively decreases as the stem is traversed from pith to bark(2). For the purposes of the present paper radiata pine stems have been divided into two categories:

Stemwood which consists of the first 10 to 15 growth layers from the pith and is predominantly corewood.

Stemwood which consists of wood outside and including the twentieth growth layer from the pith and is predominantly slabwood.

The types and qualities of chemical and mechanical pulp fibres available from radiata pine wood are discussed.

RESULTS AND DISCUSSION

Chemical pulps

Fibre dimensions: The lengths and cross-sectional dimensions of fibres in nine corewood, nine slabwood, and seven roundwood kraft pulps which were prepared from nine radiata pine trees(3) are discussed. Corewood kraft fibres are thin walled (6.2 to 7.7 μm) and short (2.7 to 3.1 mm) when compared with those in slabwood furnishes which are respectively 6.8 to 9.9 μm and 3.0 to 3.7 mm (Table 1). For fibre populations in each of the nine corewood and nine slabwood pulps wide variations in fibre length and wall thickness distributions occur (Fig. 1,2). Whereas the majority of the pulps are readily classified into slabwood and corewood groupings strong deviations from normality often exist. Tree 3 is one of these exceptions with very long thick walled fibres in both the slabwood and corewood pulps. Surprisingly the diameters and diameter distributions of the slabwood and corewood fibre populations are similar (Fig. 3). Irrespective of previously shown differences(4) in the earlywood : latewood proportions of corewood (55 : 45) and slabwood (44 : 56), overall pulp fibre diameter populations are similar. Examination of Figure 4 confirms these quantitative findings and shows that although corewood tracheids have thinner walls their range of diameters is generally similar to those of slabwood tracheids. The differences in wall thickness between radiata pine corewood and slabwood pulp fibre populations are evident from Table 1 and Figure 5.

Table 1
Wood and fibre properties

Tree number		Chip basic density kg/m³	Weighted average pulp fibre length mm	Fibre wall thickness μm	Fibre diameter μm	Fibre lumen diameter μm
Corewood:	1	388	2.71	7.39	40.74	25.97
	2	386	2.68	7.24	41.24	26.76
	3	415	2.88	7.75	42.30	26.80
	4	414	2.88	6.99	40.57	26.59
	5	450	2.75	7.54	38.60	23.52
	6	378	2.67	6.20	38.42	26.02
	7	387	3.15	7.12	41.08	26.84
	8	392	2.93	7.10	40.40	26.21
	9	406	2.81	7.45	42.95	27.97
Slabwood:	1	498	3.30	8.61	40.32	23.10
	2	409	3.20	7.76	43.03	27.51
	3	531	3.69	9.87	42.01	22.26
	4	445	3.52	8.23	42.10	25.64
	5	505	3.13	8.12	37.15	20.90
	6	432	3.09	7.05	39.49	25.40
	7	457	3.36	7.80	41.16	25.56
	8	461	3.07	7.45	38.14	23.20
	9	473	2.99	6.82	36.89	23.25
Composite sample 'rings':	10	371	2.72	6.57	38.90	25.76
	15	382	3.03	6.35	39.49	26.79
	20	401	3.17	7.26	40.98	26.46
	25	399	3.15	7.07	41.07	26.93
	30	405	3.02	7.93	40.71	24.84
	35	414	3.08	7.62	41.37	26.13
	40	426	3.12	7.93	41.07	25.21

Statistical significance:
Mean pulp fibre length different at the 95% level if differs by more than 0.21 mm.
Mean fibre wall thickness different at the 95% level if differs by more than 0.77 μm.
Mean fibre diameter different at 95% level if differs by more than 3.05 μm.
Mean lumen diameter different at the 95% level if differs by more than 2.97 μm.

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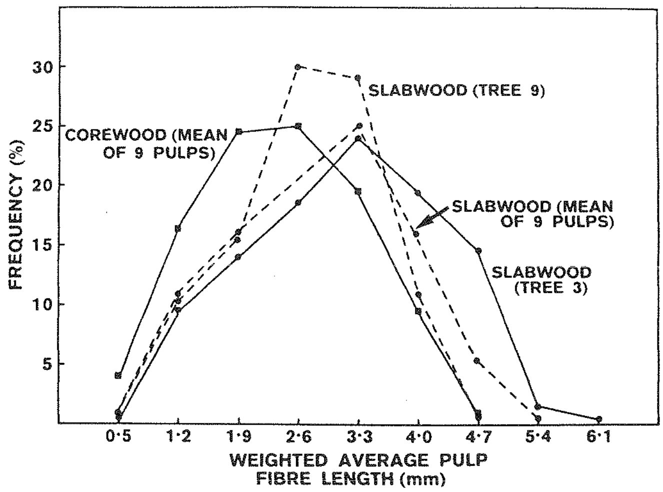


Fig. 1 — Kraft pulp fibre length distributions.

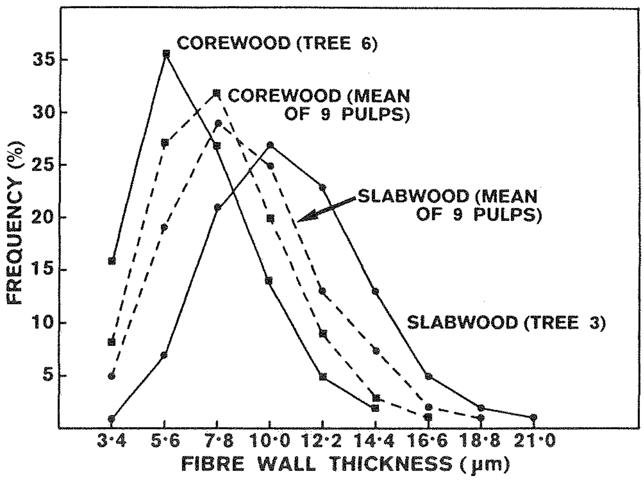


Fig. 2 — Kraft pulp fibre wall thickness distributions.

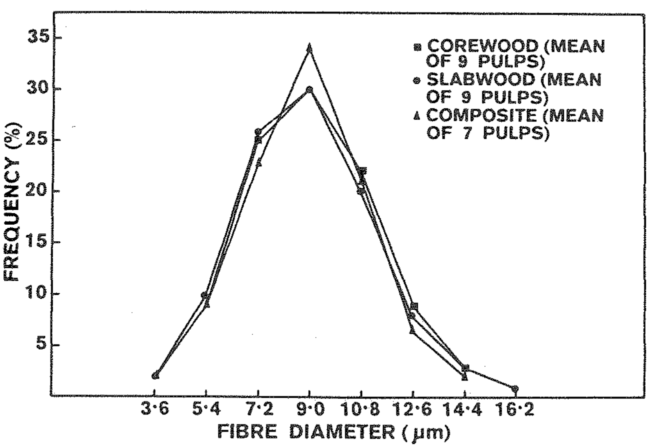
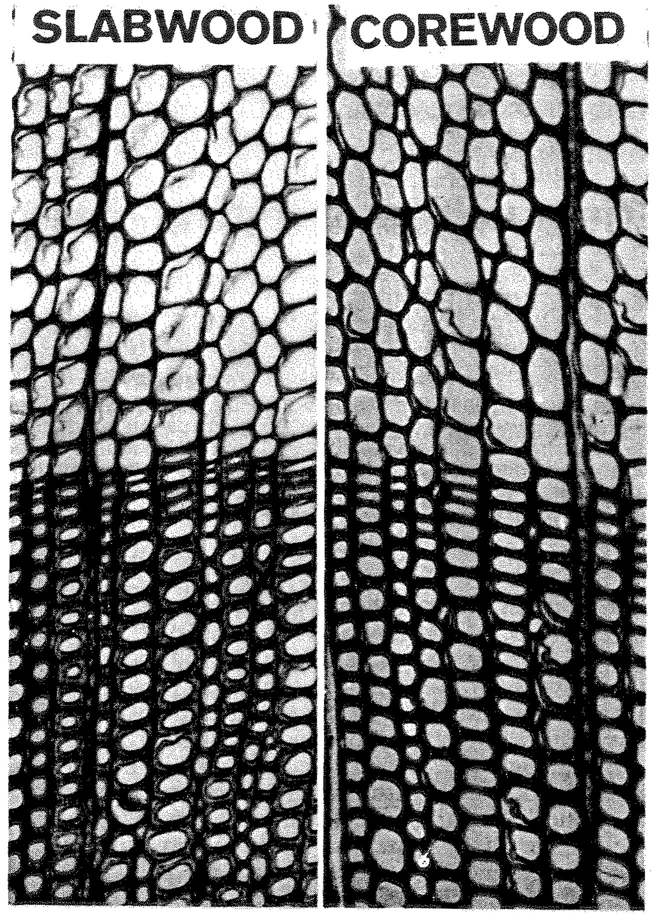


Fig. 3 — Kraft pulp fibre diameter distributions.



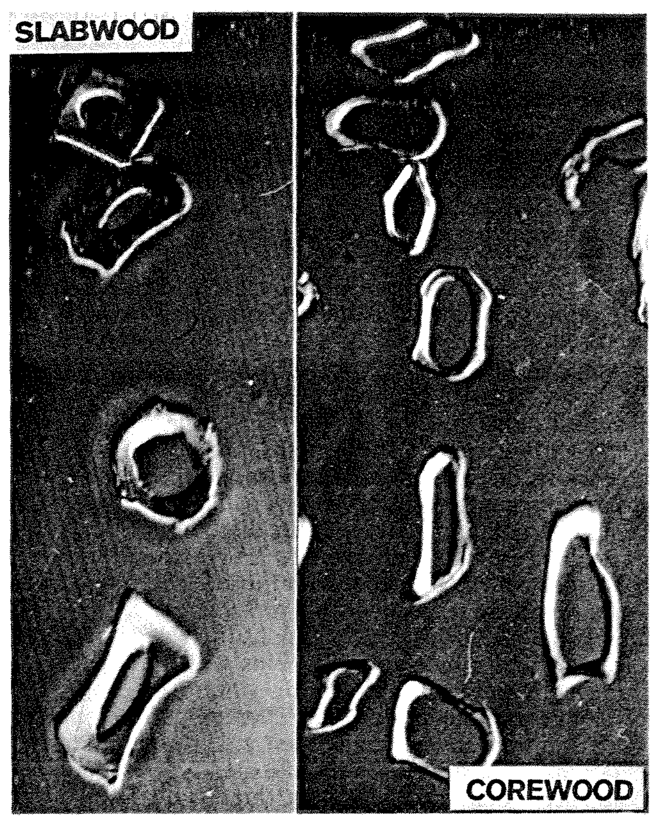


Fig. 4 (above, right) — Radiata pine corewood and slabwood tracheid cross-sectional dimensions. The corewood earlywood and latewood tracheids have thinner walls but their range of diameter is roughly similar to that of the slabwood tracheids.

Fig. 5 (right) — Radiata pine corewood and slabwood kraft pulp fibre cross-sectional dimensions.

Laboratory handsheets: Recent studies show that the fibre wall thickness : diameter ratio is highly correlated with wood basic density and in turn with handsheet strength(3). In fact it has been clearly shown that about 80 per cent of the variation in handsheet tear, burst, and apparent density is explained by the wall thickness : diameter ratio. The influence of pulp fibre length is by itself small when compared with that of the above ratio.

The thin walls but similar diameters of the corewood fibres account for their greater flexibility and collapsibility when compared with corresponding slabwood material (Fig. 6). The corewood fibres have ribbonlike configurations and are extensively conformed and bonded one to another when examined in sectioned handsheets. Slabwood fibres on the other hand have rodlike configurations and the extents of interfibre conformation and bonding are relatively small. The micrographs of Figure 6 illustrate how the collapsed and ribbonlike corewood fibres can promote web consolidation and interfibre bonding. Handsheets prepared from this type of softwood fibre have high densities, high burst and tensile indexes, and low tearing indexes. The corresponding rodlike slabwood fibres produce handsheets with relatively low densities, low burst and tensile indexes, and high tear indexes.

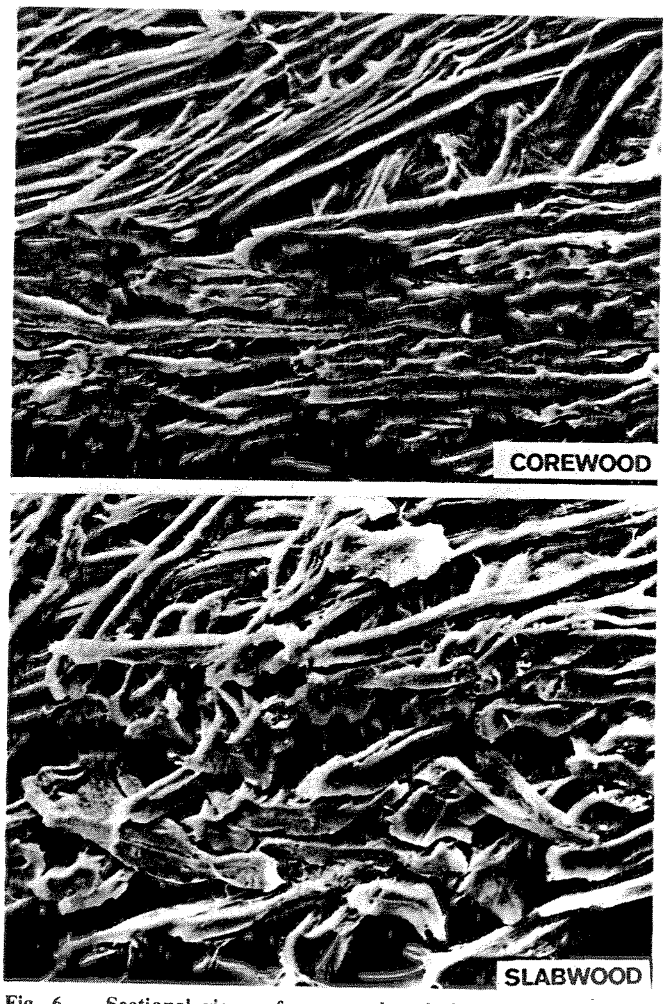


Fig. 6 — Sectional views of corewood and slabwood kraft fibres within handsheets. The corewood fibres are very much more collapsed and bonded one to another than are the slabwood fibres.

Machinemade paper: The effects of corewood and slabwood fibres on the properties of machinemade papers are similar to those described for handsheets although other factors are also important(5). For instance, it has been found that the use of corewood or youngwood fibres in fine papers substantially improves formation. Improved machine operation and product quality are also obtained when typically corewood fibres are used in the manufacture of low density paper such as saturating base. For packaging grades such as sack kraft, which require high tear strength and good tensile energy absorption, slabwood quality fibres are required.

For the low grammage, high density, specialty papers such as one time carbonizing, corewood quality or low density radiata pine fibres are necessary prerequisites to obtain satisfactory pulp refining, machine operation, and product quality(6). In the manufacture of such low grammage papers (11 to 19 g/m^2) which are produced from heavily refined pulps (CSF <50), it has been found imperative that the number of stiff, thickwalled fibres in the papermaking furnish be minimized. The presence of such fibres in a low grammage one time carbonizing furnish causes discontinuities and ultimately weak sites to develop in the formed web where pinholes and breaks can initiate (Fig. 7,8). These effects are minimized by using thinwalled (Fig. 2) and short (Fig. 1) corewood fibres with their low proportion (45 per cent)

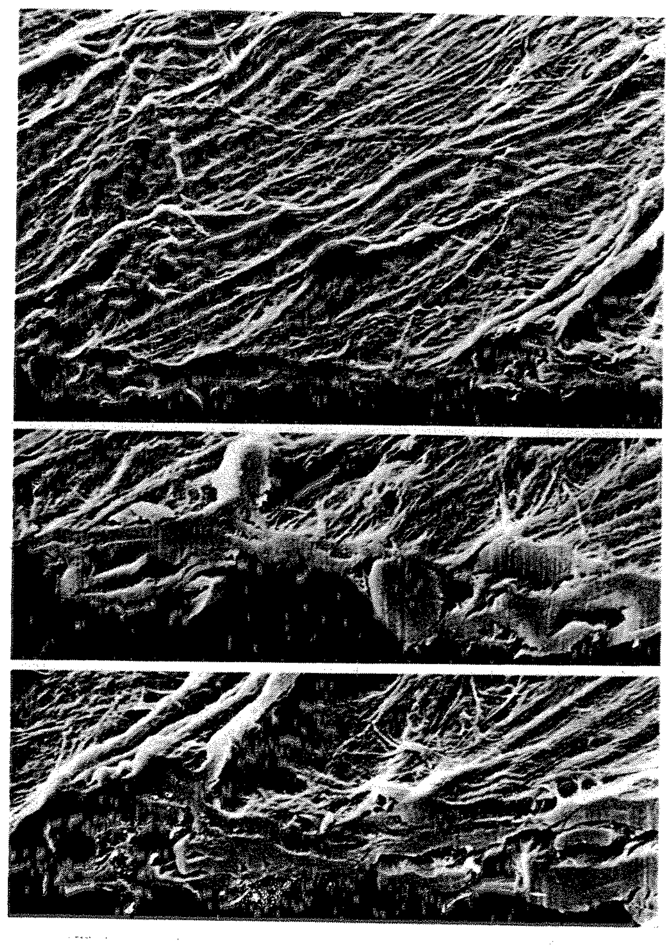


Fig. 7 — Rodlike or uncollapsed fibres in a low grammage high density paper web. There is little doubt that such fibres form discontinuities within such heavily refined, low grammage, fibre networks.

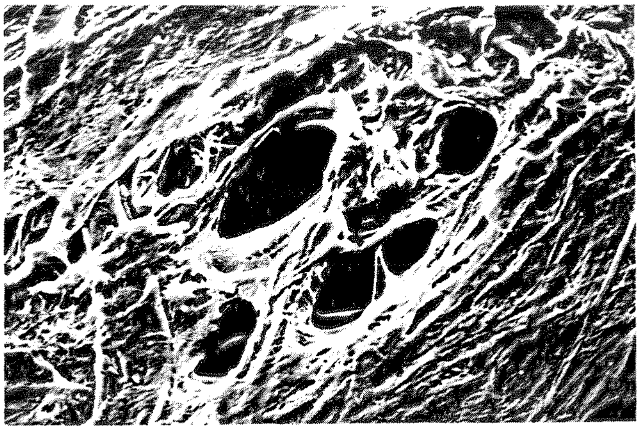


Fig. 8 — A large multiple pinhole formed about a relatively stiff fibre.

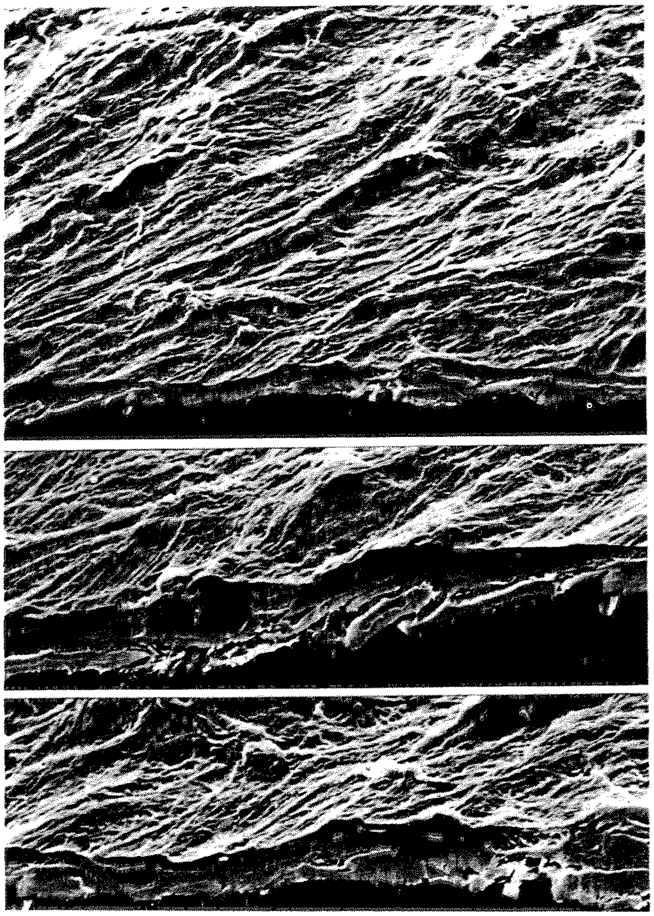


Fig. 9. — A well formed homogenous low grammage paper web which consists of collapsed and ribbonlike fibres which are generally strongly conformed and bonded to one another.

of latewood characteristics(4). Such fibres produce homogeneous and well formed webs (Fig. 9) when compared with those manufactured from run of the mill radiata pine pulps (Fig. 7). The use of radiata pine youngwood pulps has brought about significant improvements in refining and machine efficiencies, and in formation and product qualities.

Handsheet optical properties: Twenty-five kraft pulps with similar Kappa numbers (27 ± 2) are discussed (Table 1). Handsheet optical properties as shown by changes in light scattering coefficient are affected only slightly by large changes in fibre density as measured by the wall thickness : diameter ratio(3) or fibre length (Fig. 10). On the other hand when compared at given sheet densities a wide range of light scattering coefficients is obtained with individual slabwood pulps having lower sheet densities than their corewood counterparts (Fig. 11) [as expected(3)]. At given sheet densities long and thick walled fibres (Tree 3, Table 1) and short and thin walled fibres (Trees 2 and 6, Table 1) from both the corewood and slabwood pulps have respectively the lowest and highest scattering coefficients. It is the collapse behaviours and packing arrangements of these 18 very different fibre populations which determine handsheet densities and ultimately their optical properties. Thus light scattering coefficient is strongly influenced albeit indirectly by changes in the qualities of radiata pine papermaking fibres.

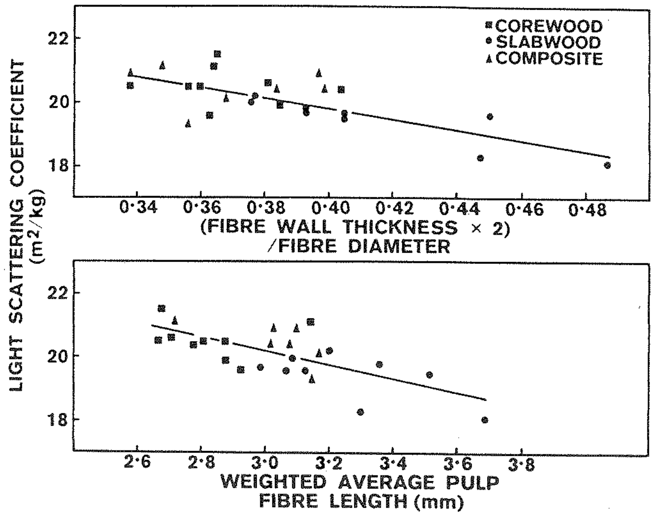


Fig. 10 — Handsheet light scattering coefficient and pulp fibre dimensions. (All pulps were given 2000 rev in a PFI mill at 10 per cent stock concentration and an applied load of 1.77 N/mm before sheet making).

Previous studies have described the effects of the earlywood and latewood components of radiata pine corewood and slabwood on kraft handsheet strength and optical properties(4). The lengths and cross-sectional dimensions of the fibres in these somewhat homogeneous pulps were also shown to strongly influence handsheet optical properties when compared at given densities and strength values. In accordance with the data listed in Table 1 the earlywood and latewood corewood fibres are short with similar diameters and thin walls in comparison with those in corresponding slabwood(4). The earlywood and latewood fibres also contained numbers of fibres per gram similar to those of their parent corewood ($>7 \times 10^5$) and slabwood (about 5×10^5) furnishes(4). Thus the different scattering coefficients obtained at given sheet densities for the corewood and slabwood pulps can be explained by the interactive packing and bonding effects of their respective fibres in handsheets.

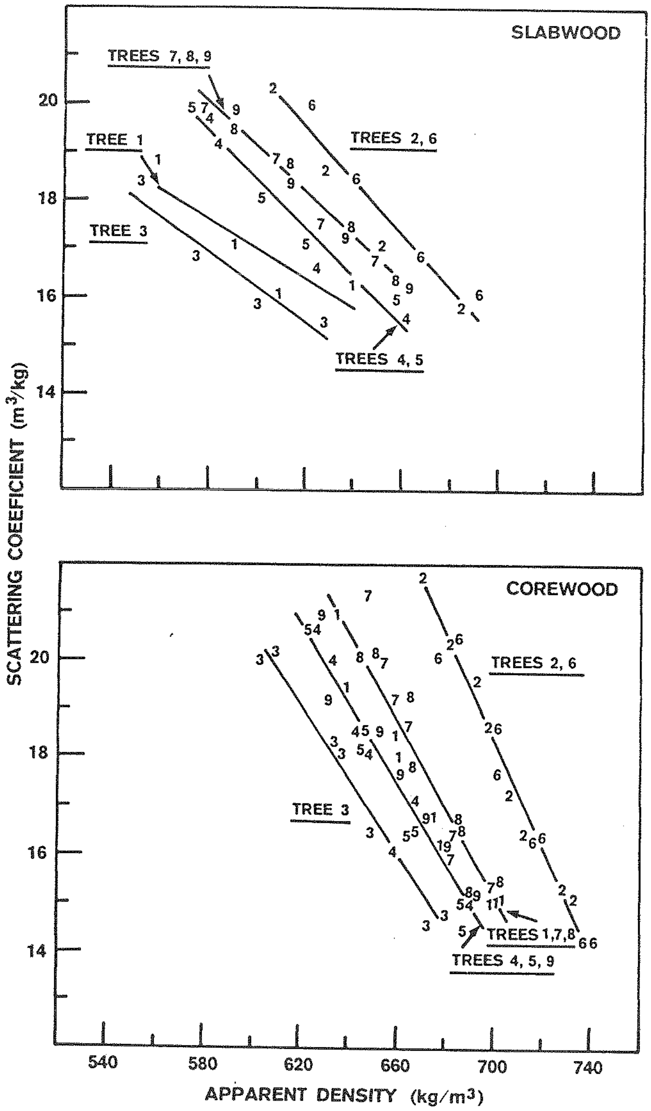


Fig. 11 — Handsheet light scattering coefficient and apparent density.

It is noteworthy that the lengths, diameters, and wall thicknesses of radiata pine fibres in no way correspond to those of hardwood fibres. Values for New Zealand silver, red, and hard beech (*Nothofagus* species) kraft fibres(7) are listed in Table 2 for comparison. These typical hardwood fibres are clearly very much smaller and denser than those in the corewood and slabwood radiata pine pulps. Thus their light scattering and opacifying capabilities in paper webs must also be very much greater than those of the softwood fibres.

Table 2
Radiata pine and beech fibre dimensions

Kraft pulp	Fibre length mm	Fibre diameter µm	Wall thickness µm	Wall thickness/diameter
Silver beech	0.77	18.2	4.7	0.26
Red beech	0.78	18.5	4.8	0.26
Hard beech	0.92	20.4	6.2	0.30
Radiata pine:				
corewood	2.8	40.7	7.2	0.18
slabwood	3.3	40.0	8.0	0.20

Earlywood and latewood fibres: Segregation of radiata pine kraft fibres according to quality prior to product manufacture could be increased further if the corewood and slabwood pulps are separated into thin walled earlywood and thick walled latewood fractions. Earlywood mean pulp fibre lengths are normally slightly shorter by up to 0.1 mm than those of corresponding latewood pulps(4). Long fibre (3 to 4 mm) slabwood pulps could therefore be segregated into thick walled (4.0 µm) and thin walled (2.9 µm) latewood and earlywood fractions respectively(4). Furthermore the short fibre (2 to 3 mm) corewood pulps could be separated into 'thinner' thin walled (2.4 µm) and 'thinner' thick walled (3.7 µm) groupings when compared with those from the slabwood furnish. The various earlywood and latewood pulp fractions could be used, either in combination with other furnishes or by themselves, to enhance the properties of certain papers or paperboards.

Compression wood fibres: Radiata pine compression wood fibres have thick walls, narrow diameters, and intermediate lengths when compared with those of normal-wood corewood and slabwood pulps(4). The handsheet properties of compression wood fibres vary with fibre dimensions and fibre densitites in the same way as normal-wood material except for stretch. The unique characteristics of compression wood fibres [absence of an S_3 layer, spiral checking within the S_2 layer(8,9), a low micellar angle(10), and an anomalous S_1 layer(4)] have been used to explain the high extensibility of handsheets prepared from them. Thus the major proportion of the increased handsheet stretch obtained with compression wood fibres is related to fibre rather than fibre network extensibility.

Future radiata pine wood supplies to pulp mills are expected to contain 10 to 15 per cent only of mild compression wood(11). This is expected to have negligible effects on overall papermaking fibre qualities.

Chemical composition: The influence of tree age on the chemical composition of radiata pine wood has recently been reviewed by Uprichard(12). For corewood which consists of the first 10 to 15 growth layers from the pith lignin and pentosan contents decrease and cellulose contents increase in the pith to bark sequence. These decreases and increases become negligible in the outerwood or in wood produced outside about the fifteenth growth layer from the pith. Effects of these differences in wood composition on the qualities of kraft papermaking fibres are minimal when compared with differences in fibre dimensions(4). Composition differences between the earlywood and latewood components of radiata pine corewood (youngwood) and slabwood (maturewood) pulps and wood samples are generally small (Table 3). The corewood samples are however slightly richer in xylose than are corresponding slabwood samples. Compression wood is rich in lignin and galactose and poor in glucose and mannose when compared with normal wood(13,14). These differences are minimized although not eliminated by kraft pulping.

Fibre modification by pulp refining: Radiata pine kraft fibres respond to pulp refining treatments in the expected manner. Fibre walls are delaminated(15), internally fibrillated(16), and fractured and dislocated to different extents depending on the refining treatment (17). Furthermore fines are produced by the removal of material from fibre surfaces(18) and fibres can be either kinked or straightened(19) depending on the refiner type and refining conditions.

Radiata pine kraft pulps do however contain a wide range of fibre qualities (Table 1) which in turn can be affected to different extents when these various fibre types are refined together. Examination of heavily refined run of the mill radiata pine kraft pulps (CSF about 20) showed that certain fibres retained their identities and configurations, and caused obvious discontinuities in the formed low grammage paper webs (Fig. 7). Certain thick walled latewood fibres were modified to only minimal extents by the refining treatment (Fig. 12).

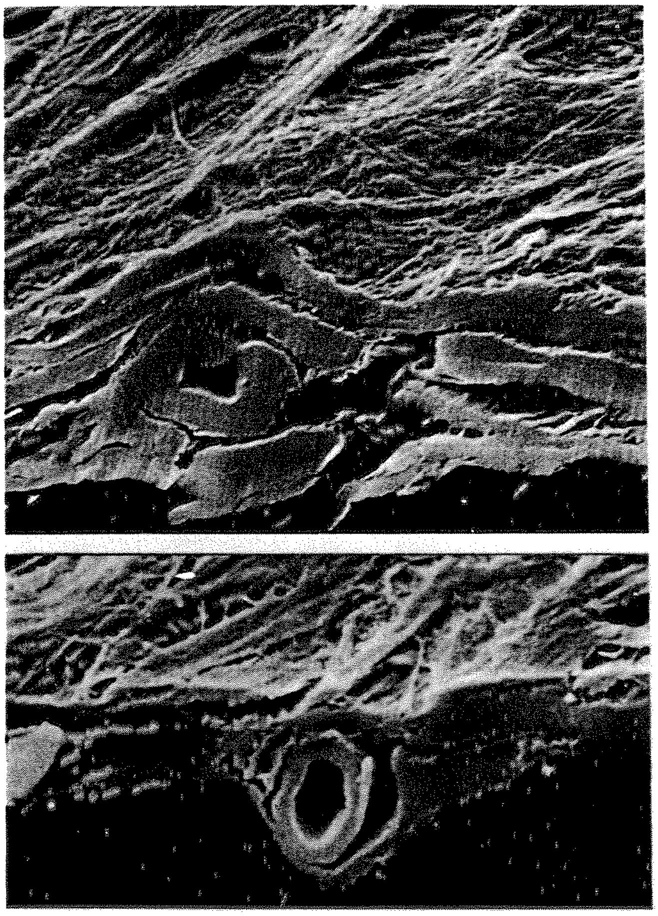


Fig. 12 — Isolated, uncollapsed, and essentially unrefined latewood fibres in a low grammage paper web prepared from run of the mill radiata pine kraft pulp of CSF <20.

It has been shown that heterogeneous pulp refining and its resulting effects on machine runnability and product quality are minimized by the selection and segregation of the most suitable radiata pine raw material before processing. The alternative approach of developing homogeneous refining systems suitable for the complete range of radiata pine fibre qualities (Table 1) appears at this stage to be the least viable.

Kraft, bisulphite, and other chemical pulping processes: Radiata pine papermaking fibres with properties very different from those of kraft pulps can be obtained using alternative chemical pulping processes(20). The bisulphite pulping process for example produces pulps with very different fibre dimensions and wall organizations(21,22), chemical compositions(21,23), refining characteristics(21,24), and handsheet properties(24) when compared with those of kraft pulps prepared from the same wood source. It is noteworthy that the kraft and bisulphite processes have very definite and separate effects on fibre structure. For the bisulphite pulps wall thickness and fibre diameter, but not lumen diameter, decrease with decreasing pulp yields. Thus fibre walls are contracted only from their surface side as wall material is extracted during bisulphite pulping. In contrast kraft fibre and lumen diameters are both smaller than those of the bisulphite fibres which suggests a general tightening of the fibrillar spiral in fibre walls during kraft pulping. These substantial differences in fibre structural organization occur in conjunction with very definite changes in fibre chemistry. In particular, very different distributions of chemical components exist in the kraft and bisulphite fibres(21,23), which in turn strongly influence refining(21,24) and papermaking(24) characteristics.

Summation: It has now been shown that the basic differences in corewood and slabwood can be utilized to preselect and optimize the papermaking qualities of radiata pine chemical pulps. On the basis of their papermaking properties alone the fibre qualities inherent in this raw material can be enhanced by selection of the most suitable chemical pulping process. For instance kraft pulps made from slabwood are most suitable for the manufacture of certain packaging grades which require high tearing strengths. For products such as soft tissues and highly bonded papers, bisulphite rather than kraft pulps could be more suitable. For such products corewood rather than slabwood is the most suitable raw material. Unfortunately the quality of papermaking fibres is only one of many economic, technical and environmental criteria which need to be considered when selecting the types and sizes of future chemical pulping systems. There is little doubt that the kraft system will be the major chemical pulping system to be used in New Zealand for the next decade. In consequence it is essential that the very definite attributes of our radiata pine wood resource be both recognized and utilized.

Mechanical pulps

Few consistent or conclusive data concerning the qualities of radiata pine mechanical pulp fibres are available. Stone groundwood (SGW), pressurized stone groundwood (PGW), refiner mechanical (RMP) and thermomechanical (TMP) pulps of high quality can however be manufactured from both corewood- and slabwood-type material(25,26,27,28). To progress beyond such a situation there is a need to be able to tailor mechanical pulps for specific end uses. To do this a detailed understanding of the fibre and other components of the different mechanical pulps in relation to different radiata pine wood qualities need to be developed. Futhermore the specific roles of individual pulp components in enhancing or restricting the development of certain end product properties(29,30, 31,32,33,34) need also to be further understood and related to the New Zealand wood resources.

The fibre and papermaking characteristics of a wide range of mechanical pulps manufactured from identical and/or comparable radiata pine wood supplies are being examined. The different mechanical pulping processes (SGW, PGW, TMP and RMP) all have the ability to produce fibres, fibre fragments or fines with very different qualities. Identification and quantification of these differences should in the future allow wood resources, and mechanical pulping processes and processing options to be selected to make maximum use of fibre qualities. To do this it must first be recognized that a mechanical pulp fibre is not comparable with a chemical pulp fibre. Firstly their chemical compositions are very different; the mechanical fibres have a composition which is almost unchanged from that of the original wood whereas corresponding kraft fibres lose more than 50 per cent of their mass during pulping (Table 3). Secondly mechanical pulp fibres are stiff and brittle, shortened, split, torn and often fragmented when compared with chemical pulp fibres. Rather than consisting of populations of discrete papermaking fibres, mechanical pulps contain wide distributions of shortened and often disrupted fibres as well as ribbon, fibril and flourlike debris(29,30). Depending on the pulping process and conditions the fines proportions in mechanical pulps can range from about 50 per cent for SGW to about 10 per cent for some refined reject furnishes (Table 4).

The first stage of our studies on the fibres of radiata pine mechanical pulps concerns the identification and quantification of the unique effects of the various pulping processes on fibre configurations and structural organizations. This research has almost been completed and will in turn be used as the basis for determining the effects of selected mechanical pulping processes on the fibres of radiata pine wood of different quality (*ie* slabwood and corewood). To analyse mechanical pulps it is necessary first to separate them into component fractions. Very different fibre qualities have been identified in what are normally identical fibre populations based on conventional fibre classification procedures. Some of the qualities of radiata pine fibres developed by individual pulping processes are outlined herein. Detailed quantitative analyses of these and other mechanical pulp fibre characteristics are presented elsewhere(35).

Fibre length: The weighted average lengths and length distributions of 'intact' fibres and fibre fragments in SGW pulp fractions (+30, +50, and +100) are very different from those of corresponding RMP and TMP

Table 3
Chemical composition of radiata pine wood and kraft pulps

Wood sample	Klason lignin % on wood	Sugars % in wood hydrolysates: galactose	glucose	mannose	arabinose	xylose	uronic acid*
Corewood:							
earlywood	27.2	4.7	60.0	17.5	3.1	12.6	2.1
latewood	25.2	3.2	63.6	18.3	2.7	10.3	1.9
corewood	26.1	3.6	59.0	18.4	3.4	12.6	3.0
Slabwood:							
earlywood	26.6	2.5	68.2	16.8	2.0	8.4	2.1
latewood	25.6	2.8	64.6	17.8	1.9	9.5	3.4
slabwood	26.5	3.8	66.3	18.4	1.6	8.1	1.8
Compression wood	31.3	12.5	61.7	14.3	1.9	8.0	1.6

Kraft pulp sample	Screen yield %	Klason lignin % on pulp	Sugars % in pulp hydrolysates: glucose†	mannose	arabinose	xylose
Corewood:						
earlywood	49.9	5.9	85.5	4.6	1.0	8.9
latewood	46.9	5.0	85.5	5.7	1.0	7.8
corewood	47.5	5.6	84.4	6.4	1.0	8.2
Slabwood:						
earlywood	50.1	7.5	85.6	6.1	0.9	7.4
latewood	46.1	4.8	87.0	5.6	0.7	6.7
slabwood	49.5	6.1	86.0	6.0	0.9	7.1
Compression wood	40.4	7.5	87.0	3.8	1.0	8.2

* Uronic acid refers to material at the origin of the chromatogram and is based on a glucuronic acid standard
† Glucose refers to the combined glucose-galactose contents.

Table 4
Mean fibre lengths of pulps and pulp fractions

Pulp description	Pulp less the −100 fines fraction		Pulp fraction +14		+30		+50		+100	
	Per cent of pulp	Fibre length mm	Per cent of pulp	Fibre length mm	Per cent of pulp	Fibre length mm	Per cent of pulp	Fibre length mm	Per cent of pulp	Fibre length mm
Tasmanian groundwood										
SGW (1)	50.3	1.75	0.2		18.1	2.08	13.7	1.27	18.3	0.72
SGW (2)	50.2	1.85	0.5		17.1	2.09	13.2	1.39	19.4	0.74
refined rejects	72.7	1.49	0.4		31.2	1.84	22.1	1.21	19.0	0.71
Tasman chips										
RMP (primary)	71.5	2.07	0.4		31.7	2.70	18.2	1.74	21.2	1.07
RMP (secondary)	67.2	2.05	0.4		28.0	2.52	18.9	1.78	19.9	1.15
refined rejects	90.0	2.35	16.9	3.32	48.9	2.54	13.9	1.64	10.3	1.06
RMP (pr'mary)	77.8	2.05	6.2		38.2	2.60	16.4	1.70	17.0	1.10
RMP (1) (secondary)	64.8	2.07	1.9		27.4	2.65	15.6	1.67	19.9	1.08
RMP (2) (secondary)	74.7	1.94	3.2		34.2	2.57	17.7	1.65	19.6	1.11
TMP (primary)	73.1	2.39	15.8	3.53	38.3	2.64	10.8	1.80	8.2	1.13
TMP (1) (secondary)	64.5	2.55	7.8	3.53	35.5	2.76	11.0	1.77	10.2	1.08
TMP (2) (secondary)	64.6	2.52	6.2	3.48	35.3	2.60	11.1	1.79	12.0	1.18
TMP (3) (secondary)	66.0	2.49	10.0	3.43	35.1	2.70	10.9	1.81	9.4	1.10

Weighted average fibre length = $\sum l_i^2 / \sum l_i$

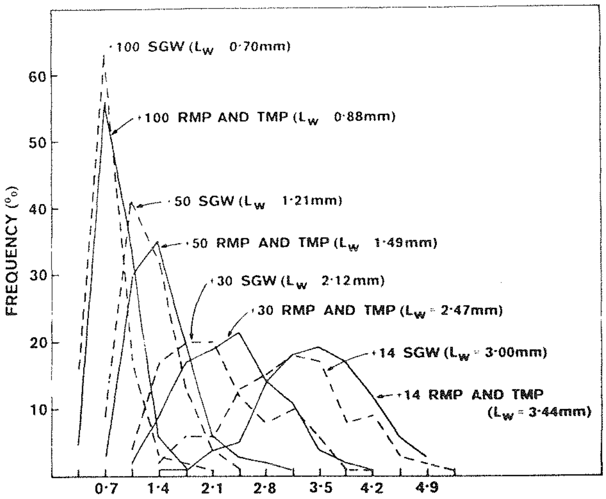


Fig. 13 — Fibre length distributions of SGW, RMP, and TMP radiata pine mechanical pulps.

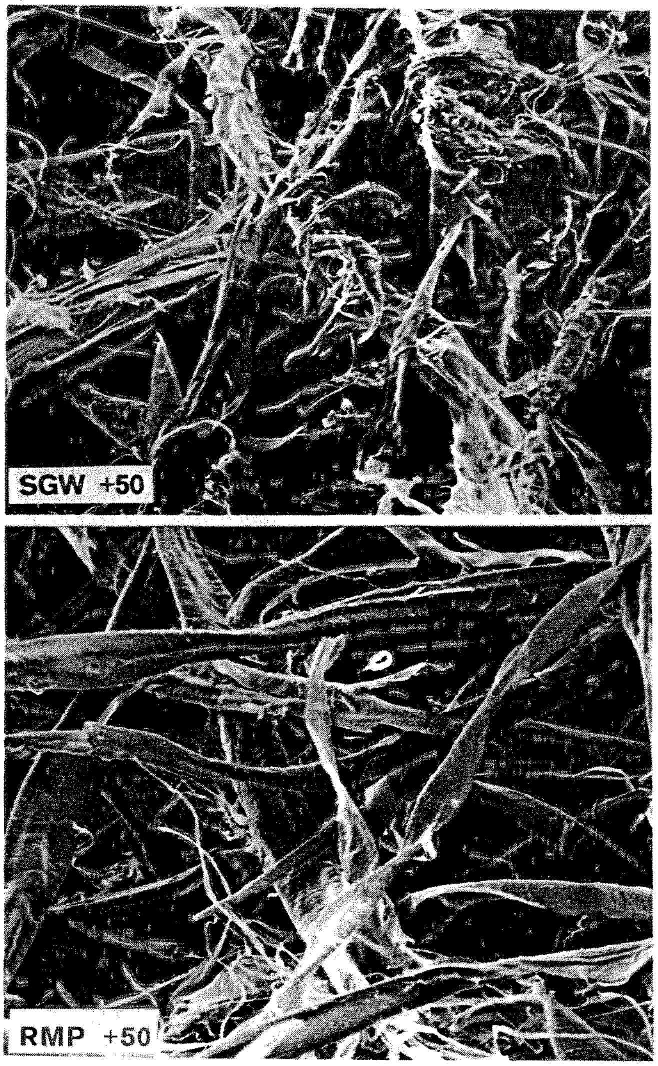


Fig. 14 — SGW fibres are more damaged and their surfaces are more torn, split and fibrillated than those in corresponding RMP furnishes. Lw is the weighted average fibre length of an individual pulp fraction.

fractions (Fig. 13, Table 4). 'Intact' fibre fragments in mechanical pulps have been defined(36) as shortened fibres with definite or collapsed lumens. Thus split fibre fragments of fibrillar debris are not included in the fibre length analyses. It is noteworthy that the existence of different fibre lengths and length distributions for the SGW pulps is contrary to the basic assumptions used by Forgacs(30) in the derivation of length factor L.

The unique wet fibre configurations or hydrodynamic specific volumes of the SGW 'intact' fibres account for their shorter lengths and different length distributions when compared with those in corresponding RMP and TMP pulp fractions. The SGW fibres are extensively damaged and fibrillated and their ends are often split and extensively frayed(35). Furthermore the SGW fibres are damaged throughout their lengths and are covered with both fibrillar and chunky debris which has been partly torn or peeled from their surfaces (Fig. 14). The TMP and RMP fibre surfaces are in contrast relatively free of debris and in this respect their configurations are as expected(31,33,34) very different from those in the SGW pulps.

Fibre and fines qualities: Examination of +100 pulp fractions shows very different fibre and fibre fragment qualities for the various mechanical pulp furnishes(36). The RMP refined reject furnish contains long ribbonlike and fibrillar fibrils which are interdispersed

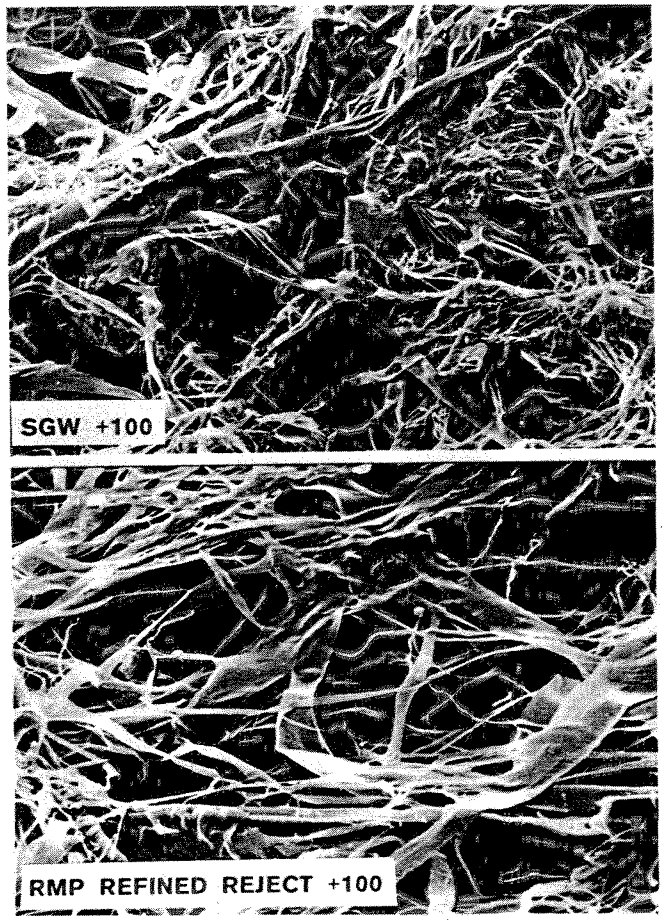


Fig. 15 — The thin but wide ribbonlike fibrils of the refined reject RMP are clearly distinguishable from the SGW with its very heterogenous +100 fraction composition.

with occassional 'intact' fibre fragments (Fig. 15). In contrast the SGW webs of the +100 fraction are less consolidated and contain fines of completely different quality. Fibre fragments are generally narrower with less ribbonlike and more fine fibrillar debris when compared with those in the refined reject RMP.

For handsheets prepared from the +200 pulp fraction (fines) the SGW furnish has the most homogeneous texture and contains the least number of 'intact' fibres when compared with the RMP [and TMP(36)] and RMP refined reject pulps (Fig. 16). The refined reject RMP web in contrast contains widely dispersed 'intact' fibres which are interdispersed between sheets of aggregated and tightly compacted ribbonlike and fibrillar (Fig. 15) fines material. Corresponding RMP webs have fibre fragments and 'intact' fibre distributions which lie somewhere between those of the SGW and the refined reject furnishes. The RMP fibre population is somewhat

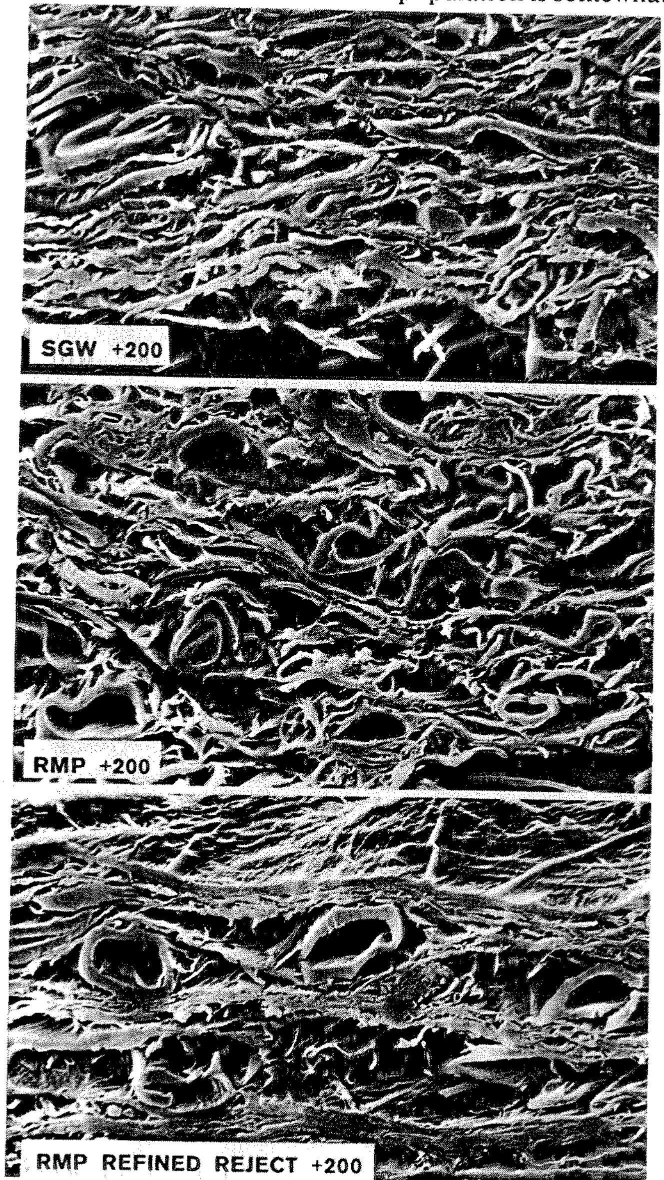


Fig. 16 — Sectioned views of handsheets of SGW, RMP, and refined reject RMP +200 pulp fractions. 'Intact' fibre numbers and configurations are very different for each of the pulps.

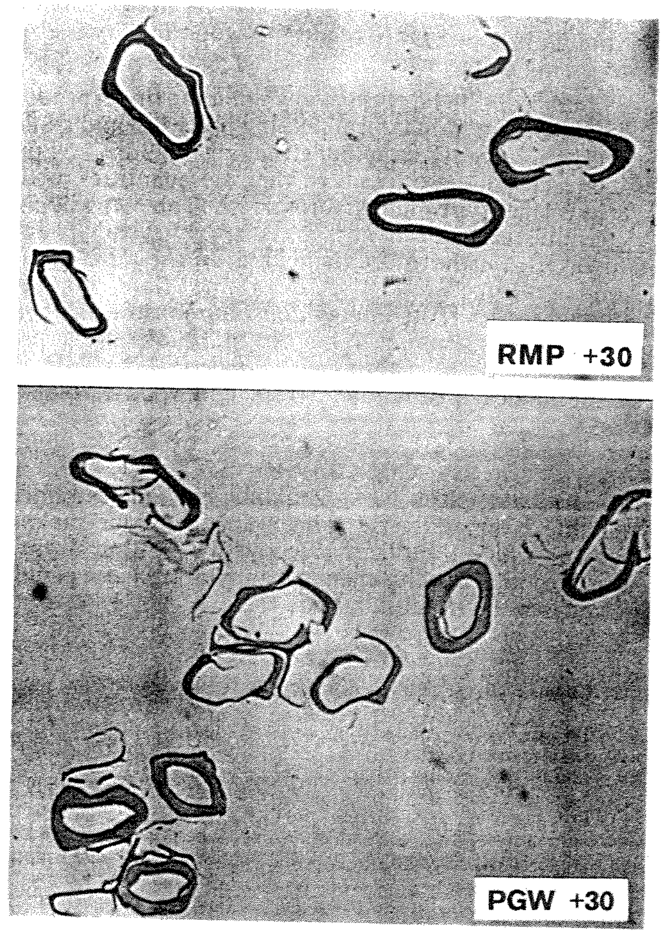


Fig. 17 — Cross-sectional views of RMP and PGW +30 fraction fibres. The dark coloured fragments of surface layers indicate middle lamella/primary wall material.

heterogeneous when compared with that of the SGW furnish.

SGW and PGW fibres: Differences exist between the qualities of fibres produced by the RMP, SGW, and PGW processes. Apart from the well known differences in fibre length(37) the extents of fibre wall damage and the retention of the middle lamella/primary wall layer on fibre wall surfaces have been found to be quantifiable methods of distinguishing SGW and PGW fibre populations (Fig. 17). For the +30 and +50 pulp fractions, the middle lamella is retained or partly retained on only about 12 per cent of the RMP fibres when compared with 30 to 35 per cent for fibres in the SGW and PGW furnishes.

Extents of fibre wall damage as measured by the number of nonintact fibre cross-sections are also different for the RMP, SGW and PGW furnishes. Whereas values for the RMP and SGW pulps are similar, with about 65 per cent of the +30 and about 52 per cent of the +50 fraction fibres having intact cross-sections, respective proportions for the PGW furnish were about 75 and 65 per cent. It was also noteworthy that for a different radiata pine wood supply and for a different SGW and PGW processing plant, the trends are completely reversed with about 70 and 65 per cent of the SGW fibres, and respectively about 58 and 48 per cent of the PGW +30 and +50 fraction fibres having intact cross-sections. This effect has yet to be explained although it is probably related to wood quality and/or processing differences.

Summation: It has been shown that the fibres produced by different mechanical pulping processes and conditions have very different papermaking qualitites. At this stage is should also be noted that the quantities of the various fibre types in a given furnish (Table 4) will also determine their effectiveness in determining end product properties. Furthermore the quality of the radiata pine wood resource will also determine fibre qualities although apart from energy consumptions during processing(28) this has yet to be proven. Studies are at present under way to determine the papermaking qualities of mechanical pulps made from corewood and slabwood.

CONCLUSIONS

In radiata pine New Zealand has an extremely valuable, very diverse and versatile papermaking resource which if utilized effectively will allow a great variety of high quality chemical and/or mechanical pulp products to be manufactured.

REFERENCES

(1) Cown, D. J. — *N.Z. J. Forestry Sci.* **10**(3): 504 (1980).
(2) Cown, D. J. and McConchie, D. L. — *N.Z. J. Forestry Sci.* **10**(3) (1980) (in press).
(3) Kibblewhite, R. P. — *N.Z. J. Forestry Sci.* **10**(3): 533 (1980). press).
(4) Kibblewhite, R. P. — *N.Z. J. Forestry Sci.* **3**(2): 220 (1973).
(5) Robertson, G. J. — Unpublished data.
(6) Hamilton, K. A. — Production experiences with radiata pine youngwood. Proceedings of FRI Symposium 23. "The Pulping and Papermaking Properties of Radiata Pine Corewood (Juvenile Wood)". Rotorua, New Zealand, 10-11 September 1980.
(7) Kibblewhite, R. P. and Brookes, D. — *N.Z. J. Forestry Sci.* **7**(3): 425 (1977).
(8) Dadswell, H. E., Wardrop, A. B. and Watson, A. J. — The morphology, chemistry and pulping characteristics of reaction wood. Pp. 187-219 in Bolam's Fundamentals of Papermaking Fibres. BP and BMA (1958).
(9) Kollman, F.F.P., and Cote, W. A. Jr. — Principles of Wood Science and Technology. 1. Solid Wood. Springer Verlag, New York, 1968.
(10) Watson, A. J., and Dadswell, H. E. — *Appita* **17**(6): 151 (1964).
(11) Cown, D. J., and Kibblewhite, R. P. — *N.Z. J. Forestry Sci.* **10**(3) (1980) (in press).
(12) Uprichard, J. M., and Lloyd, J. A. — *N.Z. J. Forestry Sci.* **10**(3) (1980) (in press).
(13) Timell, T. E. — *Wood Sci. Technol.* **1**(1): 45 (1967).
(14) Meier, H. — On the chemistry of reaction wood. "Chemistry and Biochemistry of Lignin" Symposium held at Grenoble, France, p. 405 (1964).
(15) Kibblewhite, R. P. — Transactions of the Technical Section, Canadian Pulp and Paper Association 7 (1981) (in press).
(16) Kibblewhite, R. P. — *Paperi Puu* **54**(11): 709 (1972).
(17) Kibblewhite, R. P. — *Cellulose Chem. and Technol.* **10**(2): 497 (1976).
(18) Kibblewhite, R. P. — *Paperi Puu* **57**(8): 519 (1975).
(19) Kibblewhite, R. P., and Brookes, D. — *Appita* **28**(4): 227 (1975).
(20) Harwood, V. D., and Uprichard, J. M. — *Appita* **22**(6): 153 (1969).
(21) Kibblewhite, R. P., and Brookes, D. — *Appita* **30**(4): 320 (1977).
(22) Kibblewhite, R. P., and Brookes, D. — *Appita* **31**(2): 111 (1977).
(23) Kibblewhite, R. P., and Brookes, D. — *Wood Sci. Technol.* **10**(1): 39 (1976).
(24) Kibblewhite, R. P., and Brookes, D. — *Appita* **30**(5): 395 (1977).
(25) Jensen, A. C., and Wiseman, N. — Effects of wood density on energy consumption and pulp quality in mechanical pulping. Proceedings of FRI Symposium No. 23 "The Pulping and Papermaking Properties of Radiata Pine Corewood (Juvenile Wood)". Roturua, New Zealand, 10-11 September 1980.
(26) Corson, S. R. — Mechanical pulping of young *Pinus radiata*. Proceedings of FRI Symposium No. 23 "The Pulping and Papermaking Properties of Radiata Pine Corewood (Juvenile Wood)". Rotorua, New Zealand, 10-11 September 1980.
(27) Ducker, D. J. — Mechanical pulp from 40-year-old and young radiata pine wood. Proceedings of FRI Symposium No. 23 "The Pulping and Papermaking Properties of Radiata Pine Corewood (Juvenile Wood)". Rotorua, New Zealand, 10-11 September 1980.
(28) Corson, S. R. — Mechanical pulps of new crop *Pinus radiata*. Paper presented at the 35th Appita General Conference, Rotorua, New Zealand, 6-10 April 1981.
(29) Brecht, W., and Klem, K. — *Pulp Paper Mag. Can.* **54**(1): 72 (1953).
(30) Forgacs, O. L. — *Pulp Paper Mag. Can.* **64**(C): T89 (1963).
(31) Jackson, M., and Williams, G. J. — Transactions Technical Section CPPA **6**(3): TR65 (1980).
(32) Corson, S. R. — *Pulp Paper Can.* **81**(5): T108 (1980).
(33) Mannstrom, B. — *Paperi Puu* **56**(3): 158 (1974).
(34) Mohlin, U. B. — *Pulp Paper Can.* **78**(12): T291 (1977).
(35) Kibblewhite, R. P. — The fibres of mechanical pulps. Proceedings of the International Mechanical Pulping Conference, Oslo, June 1981.
(36) Kibblewhite, R. P. — The fibres of mechanical pulps: Drying and latency effects. Paper presented at the 35th Appita General Conference, Rotorua, New Zealand, 6-10 April 1981.
(37) Aario, M., Haikkala, P. and Lindahl, A. — Pressure grinding is proceeding. Proceedings of the International Mechanical Pulping Conference, Toronto, 11-14 June 1979.

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