Refining requirements of softwood and eucalypt kraft market pulps and blends

R. PAUL KIBBLEWHITE*

* Research Scientist, Full member Appita.
PAPRO New Zealand, New Zealand Forest Research Institute Limited, Private Bag 3020, Rotorua, New Zealand.
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SUMMARY
Radiata pine and northern softwood kraft market pulps can have different refining requirements to develop selected freeness and strength properties, but such differences decrease with decreasing proportions of softwood fibre included in eucalypt:softwood pulp blends. Thus, for 80:20 eucalypt:softwood blends, freeness and tensile strength values are similar whether the softwood component consists of northern species or radiata pine pulp. It is only with refining energy demand that the 80:20 eucalypt:northern softwood blend may have an advantage over corresponding radiata pine blends. Furthermore, the same effects are obtained when furnish components are refined separately or co-refined, although separate refining requires the least energy and develops the highest tensile strengths at given freeness values.

Different bleached softwood kraft market pulps can respond to refining in very different ways (1,2). Pulps from the interior region of British Columbia, eastern Canada and Scandinavia are normally the most readily refined while those from the southern USA are traditionally the most difficult to refine to a given strength and freeness. Corresponding radiata pine kraft pulps are of good strength and have intermediate refining requirements which are less than those of Southern pine pulps but more than those of the Canadian pulps (1). Furthermore refining requirements and other properties of radiata pine pulps can vary greatly depending on their fibre qualities. For this reason low, medium and high coarseness categories of radiata pine market kraft pulp are recognized in New Zealand.

The primary objective of the present research is to identify optimum refining conditions and treatments for processing radiata pine kraft pulps and pulp blends. This paper deals with the refining requirement, freeness and tensile strength relationships of three softwood market pulps and of eucalypt:softwood pulp blends. Market krafts included in the study are radiata pine pulps of low and medium coarseness, a benchmark pulp from the interior region of British Columbia, and a eucalypt pulp from Brazil. Effects of separate and co-refining are assessed using a laboratory scale Escher Wyss conical refiner, a unit which is considered to give results indicative of commercial scale refining operations (3).

EXPERIMENTAL

Pulp origins

Radiata pine kraft market pulps of medium and low coarseness were supplied from the Kinleith mill of NZFP Pulp and Paper Limited and are used in New Zealand as standard pulps for comparison against all others. The pulps are designated Std low and Std medium.

The softwood pulp from the interior region of British Columbia was supplied by the McKenzie mill of Fletcher Challenge Canada. Pulp species composition was determined as 88:12 spruce:lodgepole pine. The McKenzie pulp is used as the benchmark for comparison with radiata pine kraft since it is recognized by papermakers to be a leading softwood market pulp.

The eucalypt pulp from Brazil was reference material 8496 supplied by Aracruz Cellulose S.A., and distributed by National Institute of Standards and Technology, Standard Reference Materials Program, Building 202, Room 205, Gaithersburg, Maryland 20899, USA.

Pulp processing evaluation

The Escher Wyss laboratory scale conical refiner, of NZFP Pulp and Paper Limited, was used to process the pulps: stock concentration 3.5%, refining speed 1500 r/min, specific edge loads 1, 3 and 5 W.s/m (softwood pulps) and 0.5, 1.5 and 2.5 W.s/m (eucalypt pulp), and refining energies 0, 40, 80, 120, 160 and 200 kWh/t.

For softwood and hardwood pulps refined separately before blending, specific edge loads were 3 W.s/m (softwood) and 0.5 W.s/m (hardwood). Pulps were blended in eucalypt:softwood proportions 0:100, 50:50, 80:20 and 100:0. Whole lap pulp including cut edges was used as the refining sample.

Softwood and eucalypt pulps were blended after Escher Wyss processing. Stock concentrations for each of the six samples from each Escher Wyss run were determined on the refined residual pulp remaining after processing. Softwood and eucalypt pulps to be blended were thoroughly mixed in a bucket by stirring, and required volumes removed with plastic containers cut to size based on predetermined stock concentration values.

For the co-refined samples whole-lap samples were blended before disintegration and refining at 0.5 and 1.5 W.s/m. Pulps were blended in eucalypt:softwood proportions 80:20 only.

Handsheets were prepared and pulp physical evaluations made in accordance with Appita standard procedures. Physical evaluation data are reported on o.d. bases.

Relative weighted average fibre length and fibre coarseness were determined using a Kajaani FS-200 instrument and standard PAPRO procedures.

RESULTS

Fibre length and pulp coarseness

Length weighted fibre lengths of the unrefined Std medium (2.46 mm) and McKenzie (2.49 mm) pulps are practically identical, although their coarseness values of 0.275 and 0.198 mg/m are very different (Table 1). In contrast, the Std low pulp contains short fibres (2.14 mm) of coarseness (0.243 mg/m) intermediate between those of the Std medium and

Table 1
Fibre properties of unrefined softwood and eucalypt pulp blends

Pulp	Eucalypt softwood blend %	FS-200 length weighted fibre length mm	FS-200 fibre coarseness mg/m	Calculated relative number of fibres per unit mass
Eucalypt	100: 0	0.74	0.082	857
Eucalypt:	0:100	2.14	0.243	100
Std low	50: 50			478
	80: 20			706
Eucalypt:	0:100	2.46	0.275	77
Std medium	50: 50			466
	80: 20			701
Eucalypt:	0:100	2.49	0.198	105
McKenzie	50: 50			480
	80: 20			707

McKenzie furnishes. As expected, the eucalypt fibres are roughly one-third the length and coarseness of the softwood fibres. Based on fibre length and coarseness, and a value of 100 for the Std low furnish, the calculated relative numbers of fibres per unit mass of each pulp and pulp blend are as noted in Table 1. Relative numbers of fibres per unit mass are generally independent of the softwood used in the 50:50 and 80:20 softwood: eucalypt blends. It is only for the unblended softwood pulps that numbers of fibres per unit mass are substantially lower for the Std medium than for either the Std low or McKenzie pulps. However the proportion of Std medium fibres in the 80:20 eucalypt:softwood blend is about 2.2% (15 out of 701) and that of the McKenzie fibres about 3.0% (21 out of 707).

The fibres of each of the three softwood pulps are shortened by about 24% when refined at 3 W.s/m (Fig. 1). In contrast, fibre lengths of the eucalypt pulp are unchanged when treated at 0.5 W.s/m (Fig. 1), and shortened by about 11% when refined at 1.5 W.s/m (4).

For the co-refined pulps, fibres are shortened only slightly when refined at the low specific edge load of 0.5 W.s/m and by up to 21% at the higher specific edge load of 1.5 W.s/m (4). In contrast unblended eucalypt fibres are only shortened by up to 11% when refined at 1.5 W.s/m which suggests that the major portion of the refining load is carried by the softwood component in the co-refined blended furnishes.

For pulps blended after separate refining, only the softwood component of a blend contributes to the shortening of fibres with Escher Wyss refining since eucalypt fibre lengths are unchanged when refined at 0.5 W.s/m (4).

Unblended softwood and eucalypt pulps

Refining energy, freeness and tensile strength inter-relations: Mean freeness values for the unrefined softwood pulps are very different whereby that of Std Medium is highest (745 CSF) and that of McKenzie lowest (650 CSF) (4). Such freeness differences between unrefined pulps continue to exist when softwood kraft pulps are refined at the same specific edge load (Fig. 2).

The unrefined eucalypt pulp is of low freeness (435 CSF) compared with the softwood pulps (4). Again the freeness difference between the unrefined eucalypt and softwood pulps remains following Escher Wyss refining.

Mean tensile strengths for the unrefined softwood pulps are very different whereby that of Std Medium is lowest (22 N.m/g) and that of McKenzie highest (49 N.m/g) (4). Such tensile strength differences between unrefined pulps continue to exist when the softwood kraft pulps are refined (Fig. 3). The tensile strengths of the unrefined eucalypt pulp lie between those of the Std low and the McKenzie pulps. The same relative differences between the softwood and eucalypt pulps occur with refining.

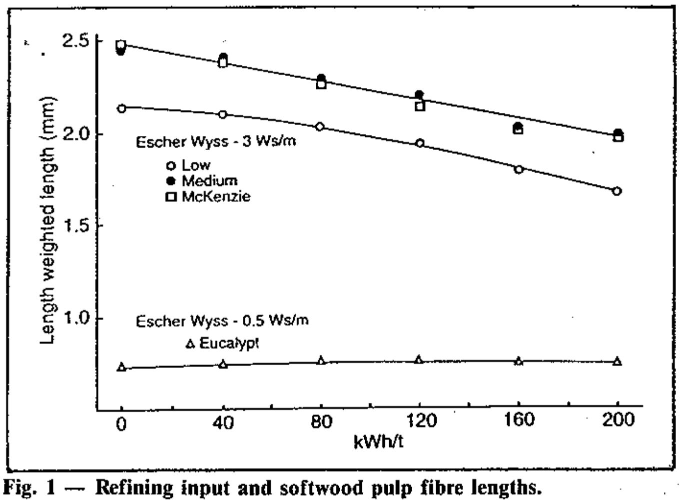

Fig. 1 — Refining input and softwood pulp fibre lengths.

Inter-relations between pulp freeness and the development of handsheet tensile strength with refining are shown in Figure 4. High tensile strengths at high freeness values are most readily developed with the McKenzie pulp. For tensile indices up to about 90 N.m/g, the McKenzie pulp has very high freeness values when compared with those of the Std low and Std medium pulps. The Std medium furnish requires the most energy to reach a given tensile strength, and tensile strength values greater than about 80 N.m/g are difficult to develop with refining. The corresponding limit for the Std low pulp is about 90 N.m/g and for the McKenzie pulp 100+N.m/g. For the Std medium pulp, therefore, the refining energy requirement is highest and the potential for tensile strength development by refining is lowest.

The low freeness of the unrefined and refined eucalypt pulp is also shown in Figure 4. For a given tensile strength

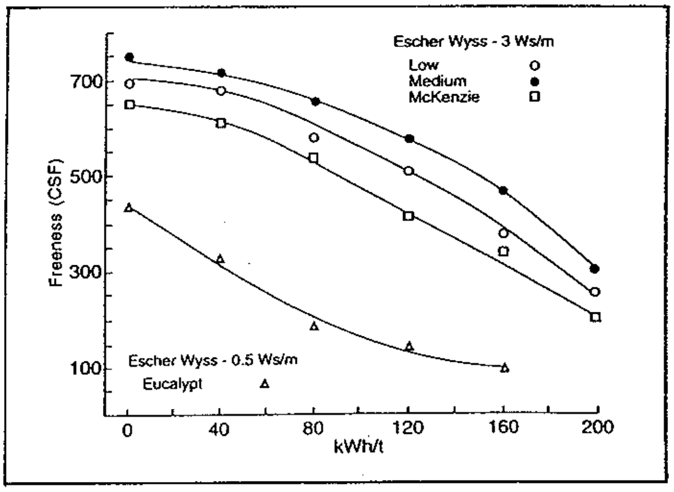

Fig. 2 — Freeness, refining energy relations for the softwood and eucalypt pulps.

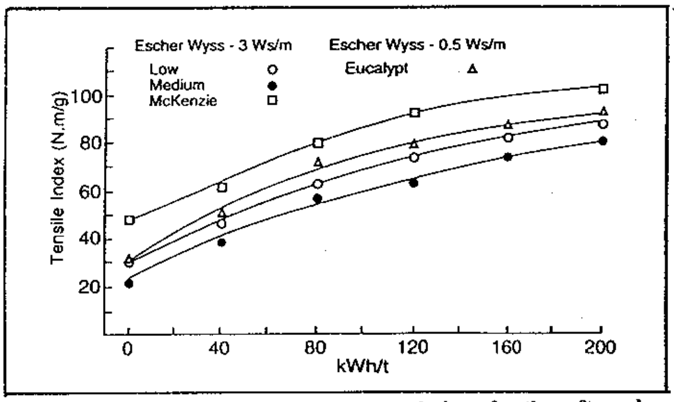

Fig. 3 — Tensile strength, refining energy relations for the softwood and eucalypt pulps.

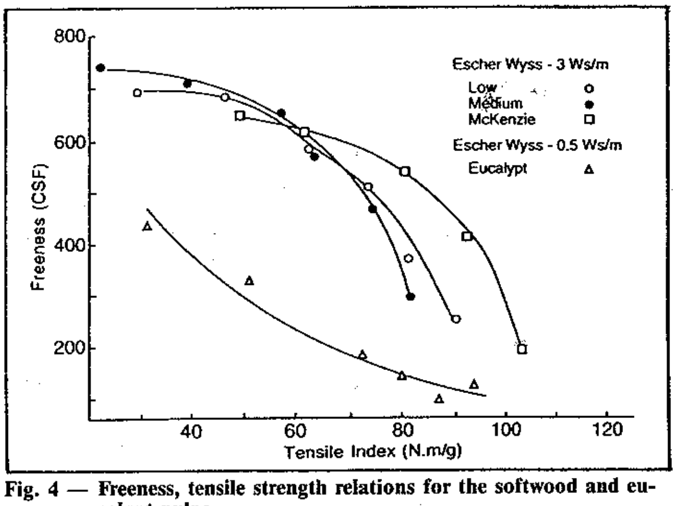

Fig. 4 — Freeness, tensile strength relations for the softwood and eucalypt pulps.

eucalypt pulp freeness values are low compared with those of the softwood pulps.

Specific edge load effects: Wide softwood pulp freeness differences are obtained with specific edge load treatments at 1, 3 and 5 W.s/m (4). While treatment at 1 W.s/m is marginally the most effective in developing handsheet tensile strengths, it is by far the least effective in decreasing pulp freeness. Similar trends are shown for each of the three softwood pulps. Thus, if manufacturing constraints and priorities demand paper machine runnability and/or high product strength, then refining at low specific edge load needs to be considered. Alternatively, if manufacturing constrains relate to energy requirements to a given freeness, then refining at an intermediate specific edge load needs to be considered.

Eucalypt softwood pulp blends

Refining energy—freeness: For a given 80:20 eucalypt:softwood blend, freeness decreases with increasing energy input and is generally independent of whether the pulp is separately refined, or co-refined at the low specific edge load of 0.5 W.s/m (Fig. 5,6). Co-refining at 1.5 W.s/m gives the lowest freeness values and the shortest fibres after energy input of about 80 kWh/t. (4).

For the Std low and McKenzie eucalypt:softwood 80:20 and 50:50 blends, freeness values at specific energy inputs are roughly equivalent (Fig. 6) (4). This freeness—energy correspondence for the Std low and McKenzie softwood eucalypt blends holds for co-refined pulps at 0.5 W.s/m, and at 1.5 W.s/m, and for pulps blended after separate refining (4). For the 80:20 and 50:50 Std medium eucalypt blends, on the other hand, energy requirements to reach a given freeness are marginally higher (4), although calculated relative numbers of softwood and eucalypt fibres per unit mass are roughly the same as those in the McKenzie and Std low blends (Table 1).

Refining energy—tensile strength: Separate refining of the eucalypt and softwood components of 80:20 blends develops high tensile strengths for given energy inputs (Fig. 7,8). Co-refining is less effective in developing tensile strength for given energy inputs. Co-refining at 1.5 W.s/m is, however, more effective in developing tensile strength than treatment at 0.5 W.s/m, except for the eucalypt Std low blends. Co-refining at 1.5 W.s/m probably selectively develops the tensile strengths of the softwood component of a blend since with separate refining of the eucalypt pulp tensile strengths decrease with increasing specific edge load (4).

For the 80:20 eucalypt:softwood blends maximum tensile strengths for given energy inputs are highest for the McKenzie blend, and similar for the Std low and Std medium blends. The high tensile strengths obtained with the McKenzie blend reflect the high tensile strength and low freeness of the unrefined McKenzie pulp (4).

For 50:50 eucalypt:softwood blends the fibre qualities of the softwood component of a blend determines overall furnish tensile and freeness properties (4). Thus, for given energy inputs, the 50:50 McKenzie blend has the highest tensile strength and lowest freeness. For the 80:20 eucalypt softwood blends, on the other hand, the influence of softwood fibre quality on tensile strength and freeness is minimal since many blend properties are primarily determined by the eucalypt component.

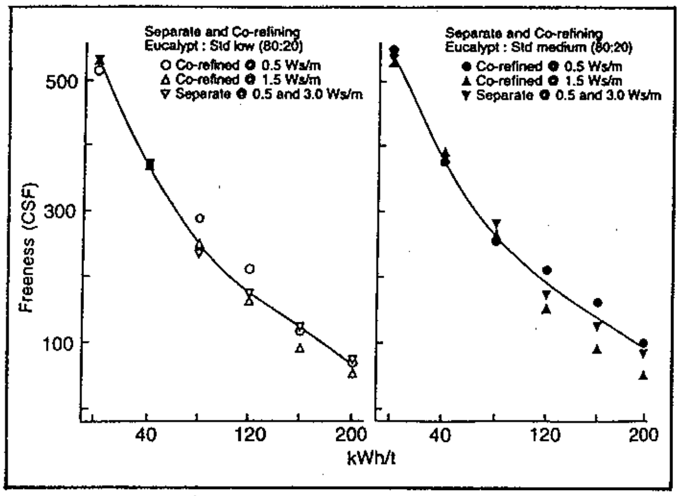

Fig. 5 — Freeness—refining energy for 80:20 eucalypt:softwood blends; Std low and Std medium pulps.

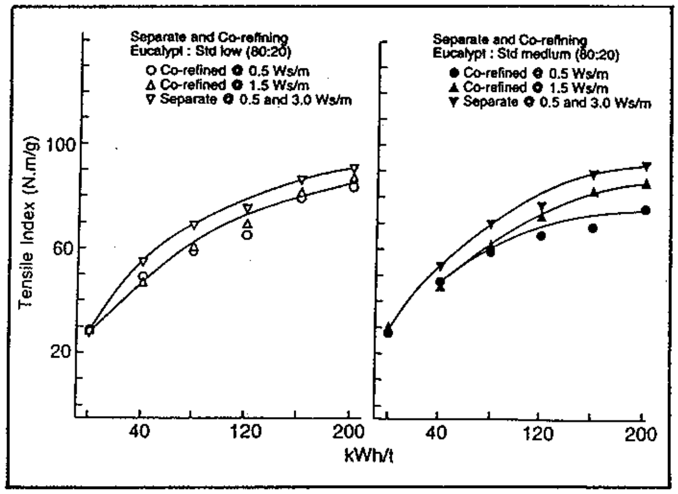

Fig. 7 — Tensile strength—refining energy for 80:20 eucalypt:softwood blends; Std low and Std medium pulps.

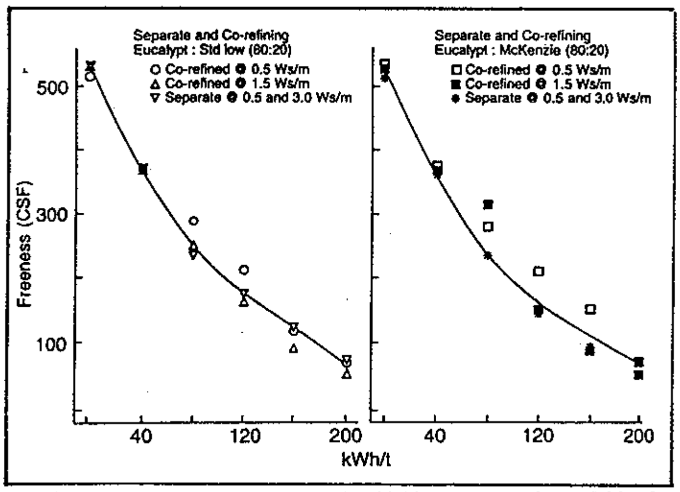

Fig. 6 — Freeness—refining energy for 80:20 eucalypt:softwood blends; Std low and McKenzie pulps.

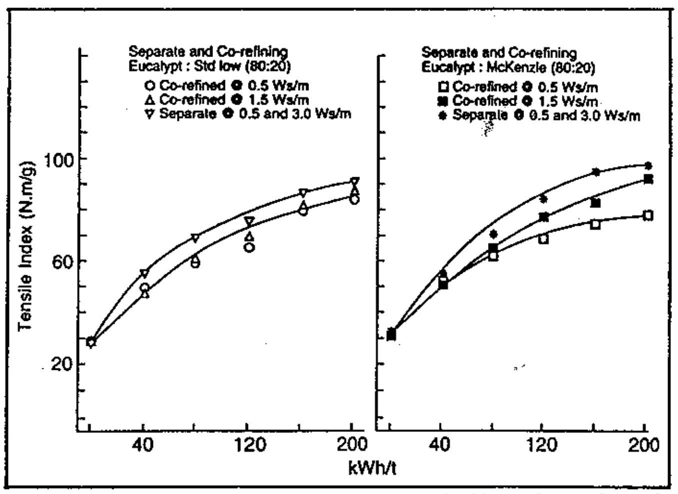

Fig. 8 — Tensile strength—refining energy for 80:20 eucalypt:softwood blends; Std low and McKenzie pulps.

Pulp freeness–tensile strength development: Separate refining of the softwood and eucalypt components of 80:20 blends is most effective in developing tensile strength at given freeness values. In contrast, corresponding co-refining treatments give lower tensile strengths at lower freeness values (Fig. 9,10). Also, unlike the tensile strength–refining energy curves of Figures 7 and 8, freeness–tensile strength relations are independent of the specific edge load used during co-refining. Finally, freeness–tensile strength relations for each of the three 80:20 eucalypt softwood blends are roughly the same, but with different regressions for the separate and co-refined treatments (Fig. 11).

DISCUSSION

Softwood pulp and refining inter-relations

The Std medium and McKenzie pulps have almost identical mean length weighted fibre lengths but very different coarseness values (Table 1). Also the length weighted population distributions for the two pulps are almost identical (unpublished data). Thus the response to refining of the Std medium and McKenzie pulps can be explained by their different coarseness values and the related relative number of fibres per unit mass of pulp (Table 1) (8). Such a statement is based on the assumption that fibre wall structural organizations are the same for the two pulps, and that their responses to refining are similar. While such an assumption may not be altogether correct, the different coarseness values of these two pulps is probably the most important variable to influence their response to refining.

The relative coarseness difference of 0.275 and 0.198 mg/m for the Std medium and McKenzie pulps can be equated to relative numbers of fibres in the respective furnishes of 77

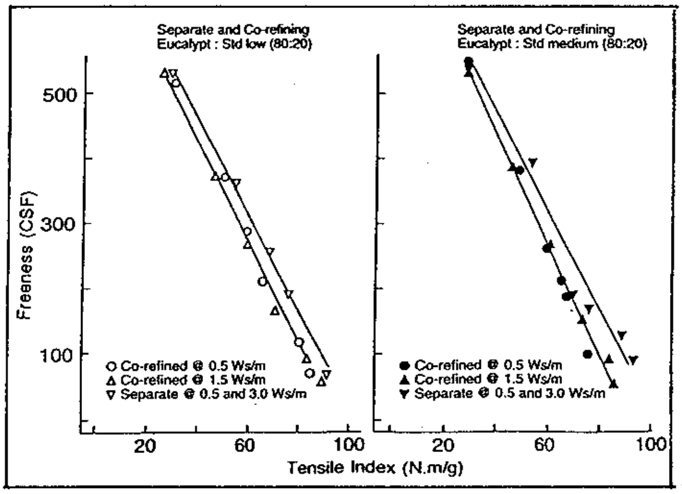

Fig. 9 — **Freeness–tensile strength for 80:20 eucalypt:softwood blends; Std low and Std medium pulps.**

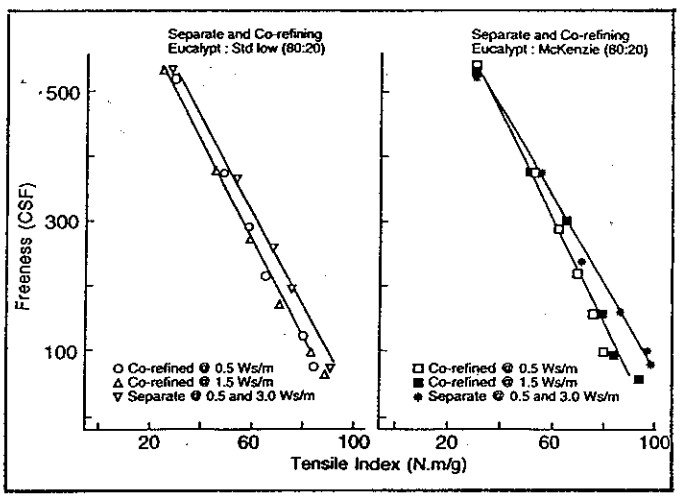

Fig. 10 — **Freeness–tensile strength for 80:20 eucalypt:softwood blends; Std low and McKenzie pulps.**

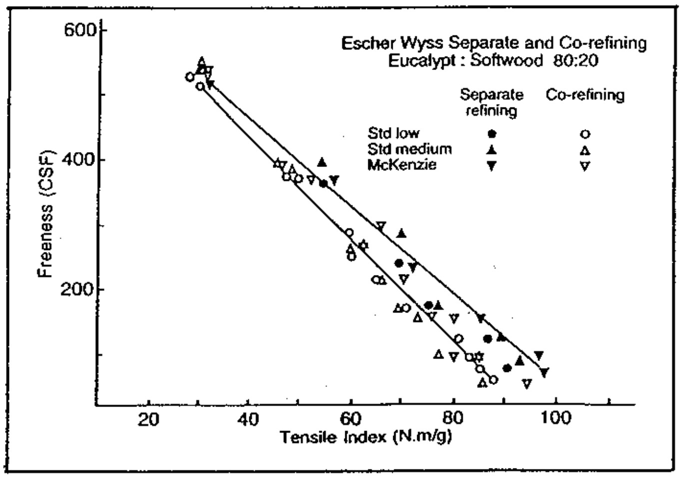

Fig. 11 — **Freeness–tensile strength for separate and co-refining 80:20 eucalypt:softwood blends.**

and 105 (Table 1). Thus the McKenzie pulp can be visualized as containing 27% more fibres than the Std medium pulp.

Comparison of the freeness–energy and tensile–energy curves for the Std medium and McKenzie pulps shows that tensile and freeness differences are determined by those of the unrefined pulps and are independent of refining input (Fig. 2,3,4). Freeness values are lower and tensile strengths are higher for the unrefined McKenzie than for the unrefined Std medium pulp. Hence no matter how much energy is imparted or what specific edge load is used, the tensile strengths developed by the Std medium pulp, for a given energy input can be expected to be always less than those developed by the McKenzie pulp. Alternatively for the same refining input, the freeness of the Std medium pulp can be expected to be always higher than that of the McKenzie pulp.

Tensile–freeness refining relations are for a papermaker indicative of the papermaking potential of a pulp. For most situations the most desirable option for a papermaker is to have a pulp of adequate strength and machine runnability at the highest possible freeness. Hence, the high tensile strength at a given freeness of the McKenzie pulp (Fig. 4) is indicative of the high regard in which this type of pulp is held by papermakers. For the Std medium and McKenzie pulps freeness and tensile values are predictable from those of the unrefined pulps. The low freeness and high tensile strength of the unrefined McKenzie furnish is in turn predictable because of high numbers of low coarseness fibres relative to the Std medium pulp (Table 1). Thus for given freeness values the Std medium pulp, which contains coarser and fewer fibres than the McKenzie furnish, develops with refining relatively low tensile strength. Such a result is predictable from corresponding values for the unrefined pulps and is independent of conventional low stock concentration refining tackle and conditions used (4,5,6,7). Based on energy requirements, therefore, the refining potentials of conventional bleached kraft market pulps are primarily determined by fibre quality. Thus the modification of fibre wall structures and/or chemistry, or the modification of refining tackle or processing conditions, are considered to be the most likely means to bring about a decrease in the refining energy requirements of hard to refine pulps.

The Std low pulp holds an intermediate position relative to the Std medium and McKenzie pulps in terms of fibre quality, refining energy and tensile strength development, and freeness–tensile strength relationships. Such an intermediate position for the Std low furnish is again related to fibre quality differences — short fibres of low coarseness relative to the Std medium furnish. The similar relative numbers of fibres for the Std low (100) and McKenzie (105) pulps reflect short fibres of intermediate coarseness for Std low, and long fibres of low coarseness for McKenzie (4).

Eucalypt:softwood pulp blends

Freeness, tensile strength and refining energy requirement differences between the three softwood pulps (Fig. 2,3,4) are eliminated or greatly minimized when blended with the eucalypt pulps either before or after refining (Fig. 5-11) (4). This effect is greatest with the 80:20 eucalypt:softwood blends. An 80:20 hardwood:softwood blend proportion is considered a realistic level for the manufacture of many printing and writing grades and therefore indicative of the refining and papermaking potentials of kraft market pulps. Furthermore, Escher Wyss refining is considered to reflect industrial low stock concentration refining operations and effects (3), and therefore the trends obtained can be expected to be indicative of blend and pulp papermaking quality. Freeness – tensile strength relations are roughly the same for the McKenzie, Std low and Std medium 80:20 eucalypt:softwood blends, although different regressions are obtained with separate and co-refining (Fig. 9,10,11). It is only in terms of refining energy requirements that the 80:20 eucalypt:McKenzie blend may have an advantage over corresponding Std low and/or Std medium blends (Fig. 7,8).

Eucalypt:softwood 50:50 blends reflect freeness – tensile strength properties which lie between those of the unblended softwood and the 80:20 eucalypt:softwood blends (Fig. 4,12). The eucalypt and three softwood pulp freeness – tensile strength properties are very different while those of the 80:20 blends are roughly the same (Fig. 4,11). Hence the eucalypt component must primarily determine freeness – tensile strength relationships of the 80:20 eucalypt:softwood blends. For the 50:50 blends, on the other hand, separate relations are obtained with the different softwood components, in particular with the McKenzie component (Fig. 12). Freeness – tensile strength properties of the 50:50 blends are, therefore, interpreted as being influenced by both the eucalypt and softwood components, as expected.

Separate and co-refining effects

Separate refining is more effective than co-refining in developing freeness – tensile strength properties for given energy inputs, although any freeness – energy differences are minimal for the two refining options (Fig. 5-11). With separate refining of individual pulp blend components before combination, refining energies and pulp responses can be optimized. For the various pulps and blend proportions used in the present research, optimum specific edge loads were selected for the separate refining of the softwood (3 W.s/m) and eucalypt (0.5 W.s/m) components. Blends were, however, made up of eucalypt and softwood pulps which received the same energy inputs (kWh/t). Thus complete optimization of refining and blend proportions would need to include an assessment of blends made up of softwood and eucalypt components refined to different degrees to optimize refining energy inputs, blend papermaking potentials, product end use requirements, and overall manufacturing cost.

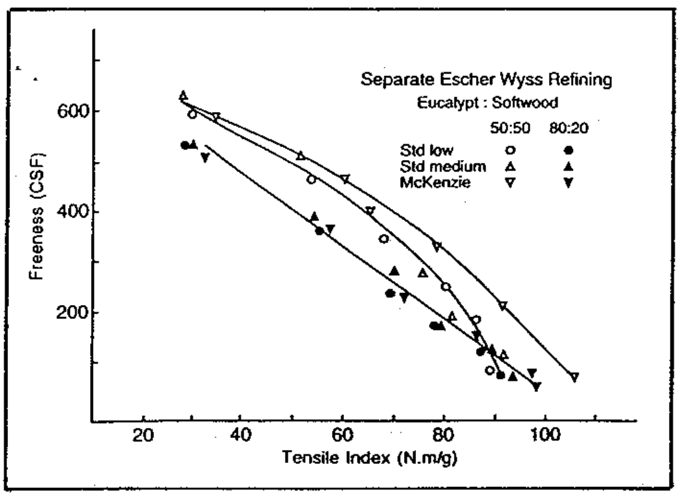

Fig. 12 — Freeness – tensile strength for separate Escher Wyss refining of 80:20 and 50:50 eucalypt:softwood blends.

Optimization of refining options and the ability to develop tensile strengths at the highest possible freeness is limited with co-refining when compared with selective separate refining. While several options remain available to the operator with co-refining (stock concentration, tackle selection, energy input etc), the option of selective refining and development of the optimum papermaking potentials of the various components of a blend is lost. For example, the tensile strengths of co-refined Std medium and McKenzie eucalypt:softwood blends can be increased with lower energy inputs by using a specific edge load of 1.5 W.s/m rather than 0.5 W.s/m (Fig. 7,8). However such gains are lower than those that can be obtained with separate refining for the three variables of freeness, refining energy input, and tensile strength (Fig. 5-11). With co-refining, therefore, any enhancement of tensile strength obtained by processing at a 1.5 W.s/m specific edge load can be expected to be lower than that achievable with selective separate refining, at lower freenesses and with higher energy inputs.

Freeness as a measure of pulp quality

Pulp freeness – tensile strength relationships can be very different depending on furnish composition, blend proportions, refining stock concentration and specific edge load, and with separate and mixed refining (Fig. 4,9-12) (4). Depending on all or any one of these pulp and/or refining variables very different tensile strengths can be obtained for specific freeness values (9).

CONCLUSIONS

The refining energy, freeness, and tensile strength interrelations of conventional softwood kraft market pulps are determined by the fibre and associated properties of the unrefined pulps. Thus, pulp quality differences present in unrefined stock are generally retained throughout refining processes. Furthermore the relative refining response of a given softwood pulp is generally independent of energy input and specific edge load.

Refining at low stock concentration (3.5%) causes differences between softwood pulps to decrease with decreasing proportions of softwood fibre included in eucalypt:softwood blends. For 80:20 eucalypt:softwood blends, freeness and tensile strength values are similar when the softwood component consists of McKenzie, Std low or Std medium pulp. It is only in terms of refining energy requirements that the 80:20 eucalypt:McKenzie blend may have an advantage over corresponding Std low and/or Std medium blends. Furthermore the same effects are obtained when furnish components are refined separately or co-refined, although separate refining requires the least energy and develops the highest tensile strengths at given freeness values.

Pulp freeness – tensile strength relations can be very different depending on furnish composition, blend proportions, refining stock concentration and specific edge load, and with separate and mixed refining.

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dryer breaks could not be attributed to the pulp using this measurement technique.

These two cases give examples of how monitoring of zeta potential distributions can provide information useful to the papermaker. In one case, the method revealed a subtle change that was not detected by other means. The ability of the DELSA technique to successfully monitor other processing steps is presently being evaluated.

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