KRAFT PULPING AND PAPERMAKING PROPERTIES OF *LARIX SIBIRICA* PULPWOOD SAMPLES AND A COMPARISON WITH THOSE OF *PINUS RADIATA*

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ABSTRACT

Larix sibirica Ledeb. (Siberian larch) pulplogs were assessed for their approximate age, and their methanol and aqueous extractives content. Kraft pulping properties were assessed using whole-log and slabwood chip samples. The slabwood chips gave pulp in somewhat higher yield than pulp from whole-log material, but the papermaking properties of their pulps were generally similar. The *L. sibirica* samples examined had rather low density for the species, and their papermaking properties reflected this. Kraft pulps were obtained from the *L. sibirica* samples in about 2% lower yield than from *Pinus radiata* D. Don, and had papermaking properties similar to those of *P. radiata* corewood (top log) pulps. They would be suitable for packaging rather than printing grades.

Keywords: kraft pulp; yield; papermaking; pulping properties; *Larix sibirica*; *Pinus radiata*.

INTRODUCTION

The kraft pulping and papermaking properties of *L. sibirica* wood samples from Russia were examined, and the properties of its pulps were compared with those of *P. radiata* grown in New Zealand. Both species are exported from their respective countries as logs, timber, or wood chips to Japan, and so their respective timber and kraft papermaking properties are of interest, since both countries are competing in the same market.

A wide variety of wood species is used by the Japanese pulp and paper industry. The forests of Siberia supply a high proportion of Japanese imports (Fenton & Maplesden 1986), a variable proportion of which is *L. sibirica*. When the kraft pulping study was undertaken (1987–88) Japan imported *L. sibirica* pulplogs, but *L. sibirica* is now imported only as sawlogs. However, wood chips imported from the eastern forest areas of Russia will still contain substantial amounts of *L. sibirica*, and *L. sibirica* wood chips will also be present in the residues from some Japanese sawmills. Substantial amounts of wood are still exported from Russia to Japan, approximately 5 million m^3 in 2000–2002 (Japan Forest Products 2002), or over a third of Japan's imported wood.

A high proportion of the *P. radiata* grown in New Zealand is exported as pulp and paper products (Uprichard 2002). However, a substantial proportion of the forest crop is also exported as sawlogs and pulplogs, or as wood chips: in 2000–2002, New Zealand exports to

Japan were between 1.5 and 1.7 million m^3. The comparison of the pulping properties of *L. sibirica* and *P. radiata* was undertaken in 1987, when some imported *L. sibirica* logs were shipped from Japan to Forest Research for assessment.

Much of the information on the kraft pulping of *L. sibirica* in the Russian literature relates to improvements in pulp processing rather than to pulp characteristics. The properties of kraft pulps from *L. sibirica* trees grown in Finland (Hakkila *et al.* 1972) and Western Canada (Hunt 1979) resemble those of pulps prepared from indigenous material. *Larix* species contain well-defined latewood bands. The thick-walled latewood fibres present in their pulps largely control their papermaking properties.

The wood chemistry and basic wood properties of *L. sibirica* resemble those of *L. decidua* Miller (European larch) and *L. kaempferi* (Lamb.) Carrière (Japanese larch) (Uprichard 1963). All contain solvent-soluble flavanoid extractives and water-soluble arabinogalactans in their heartwood. Both types of extractives influence chemical pulping behaviour. Flavanoid extractives are undesirable in acid and bisulphite pulping systems, and the arabinogalactans consume alkali during kraft pulping, so that alkali charge is increased compared with that required for pine (Nevalainen & Hosia 1969; Hakkila *et al.* 1972).

MATERIALS AND METHODS

Wood and Wood Chip Samples

The six air-dry logs of *L. sibirica* obtained from Japan were 5 m long. The logs were debarked, and 25-mm disc-type samples were taken from their base (large-end diameter) and top (small-end diameter) sections for analyses. "Whole-log" samples were prepared from butt log samples of about 1.4 m from each log. The butt log samples were sawn to 50 × 50 mm in 1.3-m lengths, which were chipped (in a small laboratory chipper): the combined chips were screened. Chips passing through 26-mm-diameter hole screens and retained on 16-mm-diameter hole screens were used for pulping. A sample of exterior slabwood (collected during the preparation of the sawn billets) was also chipped and its pulping and papermaking properties were assessed. Basic densities of the two chip samples were determined on water-saturated material, by immersion of the wood chip samples in water.

Methanol Extractives

Extractives were determined on sector samples from discs. Inner heartwood, outer heartwood, and sapwood samples of each butt log disc were ground to mesh size 20–80 in a Wiley mill: the outer radius of the so-called "inner heartwood" was at half the radius of the heartwood zone. Extractives were determined by Soxhlet extraction of the air dry ground wood (approx. 10 g) with methanol for 18 hours (Uprichard 1963), and the extract was dried to constant weight.

Aqueous Extractives

(i) The ground wood (after pre-extraction with methanol) was suspended in distilled water (150 ml) at 70°C for 3 hours, and the (cooled) aqueous extract and washings were removed by filtration. The filtrate and washings were evaporated to about 70 ml and then freeze-dried in a tared flask: the extractives were determined gravimetrically.

(ii) An aqueous extract of Log 1 was hydrolysed in trifluoroacetic acid (TFA) to its constituent sugars, prior to HPLC analysis. A known weight of extract (approx. 200 mg) was heated in a 2M solution of TFA under reflux for 3 hours, the solution was cooled, an erythitol standard added (2 ml of 5.0 mg/ml), and the mixture evaporated. The hydrolyis products were dissolved in water (20 ml), and a 5-ml sample was passed through a mixed ion exchange bed before HPLC analysis (Pettersen & Schwandt 1991).

Kraft Pulps

Kraft pulps were prepared from water-saturated wood chips. The pulps were prepared from the equivalent of 200–250 g of oven dry (od) wood using the following conditions: 18% active alkali (as Na_2O) based on od wood, liquor to wood ratio of 4:1, 24% sulphidity, and 90 minutes to maximum temperature of 170°C. Pulps with a range of Kappa numbers were prepared by varying the time at maximum temperature.

Papermaking Properties of Pulps

Pulps were beaten in the PFI mill at 10% consistency using a beating load of 3.3 N/m. Handsheets were prepared and tested according to Appita procedures. Sheet properties were compared on the basis of air dry grammage at 23°C and 50% relative humidity (sheet density data are expressed on an od basis).

RESULTS AND DISCUSSION

Basic Density and Tree Age

The *L. sibirica* pulp logs had average base diameter of 150 mm. Ring counts on the base discs indicated that the logs came from trees which were between 70 and 140 years old, or more (Table 1). The whole-log wood chips had basic density of 402 kg/m^3: the slabwood chips had somewhat higher basic density of 430 kg/m^3. To put these figures into perspective, *P. radiata* top logs or thinnings grown in New Zealand have similar wood density to those of the *Larix* samples examined, but have much faster growth rate. The *P. radiata* samples will have about twice the diameter (250 to 300 mm) and by definition (Uprichard 2002) will contain no more than 15 growth rings at their large end. The growth rate of *P. radiata* in New Zealand is between 18 and 25 m^3/ha/year (Kininmonth & Whitehouse 1991) whereas the

TABLE 1–Ring count number and base diameter of trees sampled, based on *Larix sibirica* wood-sector samples.

Tree No.	Base diameter (mm)	Ring count (No.)
1	174	74
2	147	142
3	167	78
4	141	67
5	112	85
6	167	67
Mean	151	86

growth rate of *L. sibirica* in its indigenous forest zones is between 1.1 and 1.4 m^3/ha/year (Fenton & Maplesden 1986). Pulp yield and papermaking properties of pulps are important, but ease of forest harvesting and incremental growth rate of the species of interest require equal consideration in any pulpwood evaluation study.

Extractives

Methanol extractives in the inner and outer heartwood of the larch logs were present in similar amounts, extractive content ranging from 3% to 4% of od wood. There were, on average, more aqueous extractives than methanol extractives in the *Larix* heartwood samples (Table 2). However, there appeared to be less systematic variation in the extractives of *L. sibirica* with growth ring number or heartwood content than was encountered in earlier studies on other *Larix* species (Uprichard 1963, unpubl. data). The aqueous extract from Log 1 gave a 1:5 mixture of arabinose and galactose on hydrolysis, confirming that arabinogalactan was its principal component. The high level of aqueous extractives in heartwood (about 10%) is similar to that recorded by Hakkila *et al.* (1972).

TABLE 2–Methanol extractive and aqueous extractives content of *L sibirica* wood samples.

Tree No.	Methanol extractives (%)			Aqueous extractives (%)		
	Inner heartwood	Outer heartwood	Sapwood	Inner heartwood	Outer heartwood	Sapwood
1	2.3	2.1	2.1	12.3	10.1	12.1
2	3.0	4.7	2.1	3.8	9.1	3.3
3	4.0	3.4	2.5	18.8	16.9	1.0
4	1.8	5.4	1.6	3.7	13.6	1.0
5	2.9	2.4	2.6	12.9	15.5	1.4
6	3.3	2.9	1.5	7.7	4.0	0.5
Mean	2.9	3.5	2.1	9.9	11.5	3.2

Kraft Pulping Properties

Kraft pulp of Kappa number 30 was obtained from *Larix* whole-log wood chips in 42% yield (Table 3). As expected from studies on *P. radiata* and other species (Uprichard & Gray 1983), the outer slabwood chips with their thicker-walled tracheids produced kraft pulp in higher yield than the whole-log sample. These *L. sibirica* slabwood wood chips, typical of sawmill residues, gave pulp in about 45% yield at Kappa number 30.

The *L. sibirica* whole-log samples gave pulps in lower yield than either *P. radiata* corewood (top log) or slabwood pulps at the same Kappa number. Pulp yields from *P. radiata* top logs (J.Lloyd unpubl. data) and the *L. sibirica* whole-wood pulps are compared in Fig. 1. The low yield of pulp from *L. sibirica* compared with that from *Pinus* species is probably related to its high content of arabinogalactan. The *L. sibirica* samples examined had rather low basic densities: they were similar to the low-density *Larix* samples examined by Hakkila *et al.* (1972), in which the range for basic density was between 412 and 548 kg/m^3 (mean 484 kg/m^3).

TABLE 3–Kraft pulp pulping data for *L. sibirica* whole-log and slabwood chips

Pulp type	Pulp No.	Minutes* at max. temp. 170°C	Screened yield (%)	Total yield (%)	Kappa No.
Whole-log	W20	20	43.0	47.7	80
	W40	40	42.5	44.1	51
	W60	60	41.1	41.7	37
	W70	70	42.1	42.9	33
	W90	90	41.0	41.4	28
Slabwood	S20	20	45.3	50.0	90
	S40	40	46.6	48.4	59
	S60	60	44.7	45.7	39
	S90	90	44.0	44.8	31

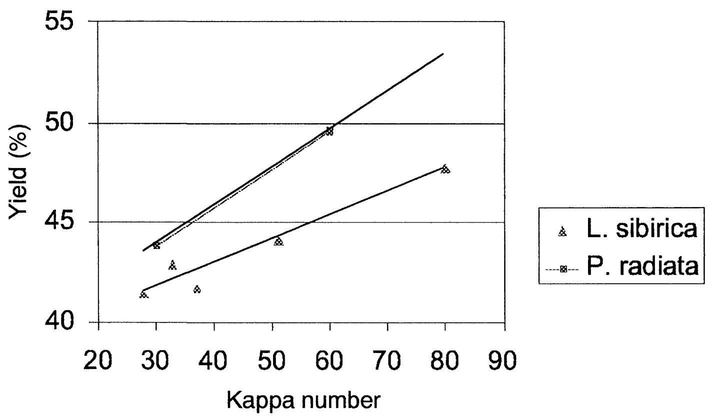

FIG. 1–Comparison of total yield *vs* Kappa number plots for *L. sibirica* and *P. radiata.*

Papermaking Properties of Pulps

The *L. sibirica* kraft pulps had good papermaking properties, the whole-log pulps and slabwood pulps having rather similar properties (Tables 4 and 5). At the same level of Kappa number, the whole-log pulp was more easily beaten and had somewhat lower tear strength than the slabwood pulp. Over the beating range examined, the pulps showed the usual increase in tear index, and corresponding decreases in sheet density, burst index, tensile index, stretch, and rupture energy, with increased Kappa number.

Properties of the whole-log pulp were rather similar to those of top log pulps from new-crop *P. radiata* (Kibblewhite & Bawden 1991) at approximately the same Kappa number (30), but appeared to have rather higher tear strength at low levels of tensile index (Fig. 2). The strength properties of the *L. sibirica* pulp closely resembled those of the low-density *P. radiata* old-crop corewood pulps examined by Corson & Lloyd (1982), and were similar in some respects to the Southern pine pulp used as benchmark by Kibblewhite (1985) in his

TABLE 4–Papermaking properties* of *L. sibirica* whole-log kraft pulps

Pulp No.	Kappa No.	Beating rev. (PFI mill)	Freeness (Csf)	Tear index ($mN/m^2/g$)	Burst index ($kPa/m^2/g$)	Sheet density† (kg/m^3)	Tensile index (Nm/g)	Stretch (%)	Rupture energy (J/m^2)
W90	28	1000	720	17.5	4.3	537	60	1.7	43.3
		2000	690	17.1	5.7	568	72	1.9	52.6
		4000	610	14.6	5.9	598	72	1.9	56.6
		8000	420	12.5	7.4	639	89	2.5	93.5
		16000	160	11.0	7.8	673	96	3.0	114.7
W60	37	1000	730	19.2	4.2	498	63	1.7	44.1
		2000	710	17.5	4.8	548	66	1.8	47.9
		4000	670	16.1	5.9	584	76	2.5	78.6
		8000	510	14.5	6.8	611	85	2.6	90.0
		16000	220	12.9	7.9	648	90	2.7	96.9
W40	51	1000	740	21.2	4.2	491	51	1.5	32.0
		2000	730	17.1	4.4	511	56	1.7	36.1
		8000	560	14.9	6.6	593	82	2.0	81.0

* Air dry grammage (23°C, 50% R.H.)
† Sheet density oven dry

TABLE 5–Papermaking properties* of *L.sibirica* slabwood kraft pulp

Pulp No.	Kappa No.	Beating rev. (PFI mill)	Freeness (Csf)	Tear index (mN/m²/g)	Burst index (kPa/m²/g)	Sheet density† (kg/m³)	Tensile index (Nm/g)	Stretch (%)	Rupture energy (J/m²)
S90	32	1000	735	20.1	3.2	485	49	1.4	28.7
		2000	665	15.7	5.4	590	70	2.2	62.5
		4000	645	16.2	5.1	602	64	2.2	55.6
		8000	470	14.8	6.8	630	81	2.6	85.6
		16000	215	11.4	7.4	659	83	2.6	84.9
S60	39	1000	715	17.2	5.1	571	56	1.7	39.3
		4000	665	17.0	5.3	591	63	2.1	60.7
		8000	515	14.6	6.4	629	79	2.6	83.3
		16000	260	13.1	6.8	654	75	2.6	79.3

* Air dry grammage (23°C, 50% R.H.)
† Sheet density oven dry

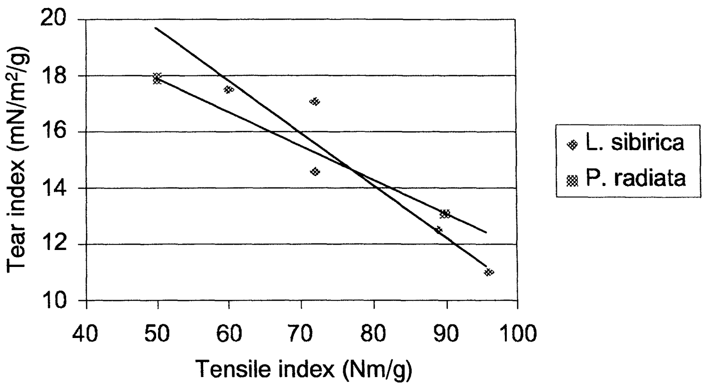

FIG. 2–Comparison of the tear index *vs* tensile index plots of *L. sibirica* whole-log pulp and *P. radiata* top log pulps.

comparison of low, medium, and high coarseness *P. radiata* pulps. Indeed, the *L. sibirica* pulp was intermediate in type, in terms of papermaking properties, between that of the low coarseness *P. radiata* pulp and that of the Southern pine pulp examined.

DISCUSSION

The *L. sibirica* examined had basic density similar to that of *P. radiata*, and was in the lower range of basic density for *Larix* spp. The heartwood of the logs examined was generally rich in water-soluble extractives, as expected. The whole-log *L. sibirica* gave kraft pulp in lower yield than *P. radiata*, probably because of its high extractive content. However, its pulps, in terms of papermaking strength, resembled those obtained from more even-textured *P. radiata* top logs. The pulps would be suitable for packaging grades, but had rather low tear strength for the species, based on the published data described earlier.

The experimental data indicate that *L. sibirica* pulplogs would compete with *P. radiata* in packaging grades, but the high level of latewood makes the species unsuitable for high-quality printing grades. *Larix sibirica* logs of higher basic density would provide kraft pulps generally similar to those of *Pseudotsuga menziesii* (Mirb.) Franco (Douglas-fir) (Hunt 1979; Uprichard & Gray 1973). Overall, *P. radiata* would provide a wider range of process alternatives, being lighter in colour and having less pronounced latewood; depending upon its quality and age, it would provide a wider range of pulp types (Kibblewhite 1985; Kibblewhite & Bawden 1991).

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