Pulping characteristics of Eucalyptus species grown in Malawi (ODNRI Bulletin No. 33)

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OVERSEAS DEVELOPMENT NATURAL RESOURCES INSTITUTE

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PULPING CHARACTERISTICS OF *EUCALYPTUS* SPECIES GROWN IN MALAWI

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SUMMARY

Eight species of *Eucalyptus, E. camaldulensis, E. citriodora, E. cloeziana, E. grandis, E. maculata, E. maidenii, E. saligna* and *E. tereticornis* grown in the Viphya plateau, Malawi, were examined to determine their suitability for the production of papermaking pulp. The size of 9-year-old trees, wood density, chemical characteristics and fibre dimensions are reported. All species were pulped by sulphate, soda and soda-anthraquinone processes. By the sulphate process all species yielded over 45% (two over 50%) of bleachable pulp with good strength characteristics. The soda-anthraquinone process yielded similar quantities of pulp, with the same kappa number and marginally lower strength characteristics. The soda process needed a more severe chemical dose to yield less pulp, with the same kappa number and much lower strength characteristics. All species were pulped, also, by the neutral sulphite semi-chemical process to yield about 70% of pulp suitable for use in packaging grades of board. One digestion by the chemi-refiner mechanical process on *E. grandis* indicated that, if conditions were optimized, pulps produced by this process should be suitable for the production of newsprint.

RÉSUMÉ

Huit espèces d'*Eucalyptus, E. camaldulensis, E. citriodora, E. cloeziana, E. grandis, E. maculata, E. maidenii, E. saligna* et *E. tereticornis*, cultivés sur le plateau de Viphya au Malawi, ont été examinés pour déterminer s'ils conviendraient pour la production de pulpe à papier. Une description est fournie de la dimension des arbres de neuf ans, de la densité du bois, de leurs caractéristiques chimiques et de la dimension des fibres. Toutes les espèces ont été pulpées par les processus au sulfate, à la soude et à la soude-anthraquinone. Au sulfatage, toutes les essences produisaient plus de 45% (et deux, plus de 50%) de pulpe blanchissable possédant de bonnes caractéristiques de résistance. Le processus soude-anthraquinone fournissait des quantités analogues de pulpe avec le même nombre kappa et des caractéristiques de résistance légèrement inférieures. Le processus à la soude exigeait une dose chimique plus forte pour fournir moins de pulpe avec le même nombre kappa et des caractéristiques de résistance bien inférieures. Toutes les essences ont été aussi pulpées par le processus semi-chimique sulfite neutre, pour fournir environ 70% de pulpe propre à l'usage sous forme de cartons d'emballage. Une digestion par le processus mécanique du chimi-raffineur sur *E. grandis* indiquait que, dans des conditions optimales, les pulpes ainsi produites conviendraient à la fabrication de papier-journal.

RESUMEN

Se llevó a cabo el examen de ocho especies de *Eucalyptus: E. camaldulensis, E. citriodora, E. cloeziana, E. grandis, E. maculata, E. maidenii, E. saligna* y *E. tereticornis*, que crecen en la Meseta de Viphya, Malawi, para determinar su adecuabilidad para la producción de pasta de papel. El informe presenta el tamaño de árboles de 9 años, densidad de la madera, características químicas y dimensiones de la fibra. Se obtuvo pasta de todas las especies por los métodos de producción al sulfato, a la sosa y a la sosa/antraquinona. Con el proceso de sulfato, todas las especies proporcionaron más del 45% (dos de ellas más del 50%) de pasta blanqueable, con buenas características de resistencia. El proceso de sosa/antraquinona produjo cantidades similares de pasta, con el mismo número kappa y características de resistencia marginalmente inferiores. El proceso de la sosa requirió una dosis química más fuerte, con un rendimiento de pasta inferior, el mismo kappa y características de resistencia muy inferiores. Se sometió asimismo todas las especies al proceso semiquímico de sulfito neutro, con el que se obtuvo alrededor del 70% de pasta apropiada para su empleo en cartón para embalaje. Una pulpación mediante el proceso mecánico quimiorrefrinador con la especie *E. grandis* indicó que, mediante la optimización de las condiciones, las pastas producidas por este proceso serían apropiadas para la producción de papel de periódico.

Pulping characteristics of *Eucalyptus* species grown in Malawi

INTRODUCTION

The Viphya forest extends 110 miles in a north-south direction along the mountain chain which forms the western wall of the Great Rift Valley. Its width varies between 4 and 10 miles. It contains the largest continuous area of land suitable for the production of pine plantations in Malawi.

Planting of pine species started in 1950, and was planned to give a final area of 21,850 ha by 1980. The pulping characteristics of samples of *Pinus patula* and *P. elliottii*, which were expected to yield 17.5 m^3 per ha per annum and be grown on a 15-year rotation, were determined at the Overseas Development Natural Resources Institute (ODNRI) in 1974 (Palmer and Gibbs, 1974). Subsequently, measurements by the Malawi Forest Department determined that *P. patula* growing on an average site had a mean annual increment of 18.1 m^3 per ha per annum over a 16-year rotation.

Later, *Eucalyptus* species were included in the planting programme. The plans were to plant about 6000 ha, to be used as fuel wood and for pulping. In 1975, a number of *Eucalyptus* species were planted as part of a species selection trial by Viphya Forest Industries, supported by the Overseas Development Administration (ODA). It was intended that these species would be grown on an eight-year rotation and that pulping properties would be included in the evaluation. In 1983, the Malawi Forest Department requested ODNRI to carry out the pulping trials. The following eight species were examined: *Eucalyptus camaldulensis, E. citriodora, E. cloeziana, E. grandis, E. maculata, E. maidenii, E. saligna* and *E. tereticornis*.

CLIMATIC AND EDAPHIC CONDITIONS

All of the samples tested were grown on the Lake Shore Plain. The climatic and edaphic conditions of the site are:

Altitude: 600 m above sea level
Soils: Free-draining stony, sandy to silty clay loams over-lying micaceous phyllonites or hornblende biotite schists.
Rainfall: Long-term average rainfall for Kawiya is (mm)

Oct	Nov	Dec	Jan	Feb	Mar	
26.0	146.9	267.5	283.7	259.1	439.8	
Apr	**May**	**June**	**July**	**Aug**	**Sept**	**Total**
385.4	101.9	48.9	42.8	6.2	8.7	2016.9

Temperature: Mean temperature determined at Nkhata Bay, on the lake shore 30 km north of the trial site is: June, 21.6°C; November, 26.5°C.
Winds: Prevailing wind is from north-east to south-east with short periods of north or north-west winds in the rainy season.

SELECTION OF SAMPLES

Each species in the trial was planted in strips. In the pulping trials each species was represented by 10 trees that were selected from different positions within the strip so that trees grown on slopes, valleys and ridges were all present.

The breast-height girth and the height of each selected tree were measured before felling. After felling, the length of the bole to 8 cm diameter over bark was determined and sampling points marked at 10, 30, 50, 70 and 90% of this length. At each sampling point discs, approximately 20 mm thick, were cut, and the over bark and under bark diameter of the discs measured.

The discs were then air-dried before being sent to ODNRI in London. Unfortunately, the discs from three *E. camaldulensis* trees and four *E. maidenii* trees were lost in transit: consequently, the samples examined of these two species were of fewer than 10 trees. Also the field sheets recording the dimensions of *E. grandis* were lost and these data could not be included in the report.

The dimensions of the trees sampled are recorded in Table 1.

There was considerable variation in the size of trees both within and between species. Within species the smallest tree had a height 70% and a diameter 50% of the largest. The average dimensions of trees from the sample with the shortest trees, *E. cloeziana*, were 60% in height and 70% in diameter of the average dimensions of the trees of the tallest sample, *E. tereticornis*. From the dimension data on these samples *E. saligna* appears to produce the most wood followed by *E. tereticornis, E. citriodora, E. maidenii, E. camaldulensis, E. cloeziana* and *E. maculata. E. grandis* is omitted from this list because the data of tree dimensions were not available.

The bark content, by volume, of *E. grandis* was 13%. For the other seven species it varied between 22 and 28%. The very low bark content of *E. grandis*, when compared with the other species, may be due to differences in technique as this value was calculated from measurements made after the samples arrived in London, whilst the values for the other species were calculated from measurements made in the field. The bark content, by weight, determined on samples of *E. camaldulensis, E. grandis* and *E. maidenii* was 16 and 17%. It was not possible to determine values from the other species as the bark had separated from the wood, whilst in transit, in such a way that it was not possible to associate the bark positively with specific volumes of wood.

EXPERIMENTAL PROCEDURES, RESULTS AND DISCUSSION

The apparent density and chemical composition of the wood were determined by the standard methods published by TAPPI, the Technical Association of the (USA) Pulp and Paper Industry.

Wood of each species was digested by three chemical processes (sulphate, soda and soda-anthraquinone (soda-AQ)) and the neutral sulphite semi-chemical process (NSSC). *E. grandis* was pulped by the chemi-refiner mechanical process (CRMP).

Suitable chemical pulps were bleached by a four-stage process of sequential applications of chlorine, sodium hydroxide, sodium hypochlorite and chlorine dioxide (CEHD).

All pulps were evaluated by beating in a PFI Mill, forming sheets on a British Standard Sheet Machine and testing the sheets, after conditioning in an atmosphere of 23°C and 50% relative humidity, by the appropriate British and International Standard Methods.

Fibre dimensions were determined by measuring and fractionation of the fibres of a well-digested sulphate pulp.

More details of the experimental techniques are given in *ODNRI Bulletin* No. 7 (Palmer *et al.*, 1988)

Wood density

The density of the wood is recorded in Table 1. *E. grandis* had wood with the lowest density, 448 kg m^{-3}, and *E. citriodora* the highest density, 674 kg m^{-3}. The density values indicated that all of the samples were suitable for pulping. However, those with higher density would be preferred as they would give greater efficiency in transport and digester utilization.

Combining data on growth rate and wood density indicates that *E. tereticornis* yields most wood per unit of area.

Chemical analysis

The chemical components which affect the pulping characteristics were determined and are recorded in Table 2.

The lignin content was between 19% (*E. citriodora*) and 32% (*E. saligna*). The holo-cellulose was between 70% (*E. grandis*) and 76% (*E. citriodora*).

The chemical data indicate that all the samples could be pulped by standard chemical processes and give reasonable yields of pulp, but samples with a high lignin content, such as *E. saligna* and *E. tereticornis*, were expected to need more severe digestion conditions.

Fibre dimensions

The fibre length was determined for each sample by fractionation of a well-digested pulp and the fibre width and wall thickness were determined by measurement of the magnified image. The values determined are recorded in Table 3.

The length of the fibres from all of the samples was less than 1 mm: *E. citriodora* had the longest fibre (0.95 mm). Fibres from the other species were between 0.88 and 0.90 mm.

Fibres from all species were slender (13.8–17.2 μm) and thin-walled (2.8–3.8 μm). These values gave a coefficient of suppleness (Width of lumen × 100)/Width of fibre of between 49 (*E. tereticornis*) and 66 (*E. grandis*). All of the samples should yield pulps with fibres of elliptical cross-section, giving good surface contact and fibre-to-fibre bonding, and, consequently, papers with good tensile and bursting strengths.

Sulphate pulping and bleaching

Unbleached pulp

To determine the pulping characteristics by the sulphate process, each sample was digested using three different levels of chemical dose. The most severe conditions (17.5% active alkali) was expected to yield a bleachable pulp, the other conditions higher yields of pulp.

Table 4 records the yield and properties of pulps obtained when identical digestions, using 15% active alkali, were carried out on each species. These pulping conditions gave screened pulp yields between 45.7% (*E. tereticornis*) and 50.9% (*E. citriodora*) and kappa numbers (a measure of residual lignin in pulp) between 26.6 (*E. maculata*) and 37.9 (*E. grandis*). The pulp strengths at a drainability value of 300 CSF were: tensile index between 87 (*E. citriodora*) and 114 (*E. grandis* and *E. maidenii*); burst index between 4.8 (*E. citriodora*) and 7.0 (*E. grandis*); tear index between 8.3 (*E. grandis*) and 12.8 (*E. tereticornis*). The values were all satisfactory for pulps from *Eucalyptus* species. The most promising species was *E. saligna* which, with a screened pulp yield of 46.6%, tensile index 109, burst index 6.3 and tear index 11.6, ranked fourth for yield, third for tensile and bursting strength and second for tearing strength.

Major differences in the pulps from different species were found in the energy required for beating and in the sheet density and air resistance. *E. camaldulensis* yielded the pulp which required least energy to beat, 3260 revolutions in a PFI mill to reduce the drainability to 300 CSF. Pulp from *E. tereticornis* required more than twice as much beating, 7640 revolutions to the same drainability level. Sheet density was in the range of 0.63 g cm^{-3} for pulps from *E. tereticornis* to 0.79 g cm^{-3} for those from *E. grandis*; sheets with high density were much more resistant to the passage of air than those with low density.

The correlations between chemical analysis values and pulp yield, and fibre dimensions and pulp strength were poor. This was probably due to the small spread of values.

Details of digestion conditions and pulp characteristics are given for individual species in Tables 6 to 9 inclusive.

Bleached pulp

The pulp obtained from each sample by sulphate digestion using 17.5% active alkali was bleached using a chlorine, alkali extraction, hypochlorite, chlorine dioxide (CEHD) sequence. Details of bleaching conditions and bleached pulp evaluation are given in Table 5.

The quantity of chlorine applied in the first stage was determined by the kappa number (lignin content) of the unbleached pulp: the remaining stages were identical for all pulps. The total amount of chlorine consumed varied from 6.7% on a pulp with a kappa number of 24.1 to 9.9% on a pulp with a kappa number of 28.1. The resultant pulps had a brightness between 87 and 89, which was a good value for a relatively simple bleaching sequence and it is likely that pulps with a brightness over 90 could be obtained by using more complex techniques and optimizing the parameters.

The yield of bleached pulp was about 5% less than the yield of unbleached, ranging from 42.9% for *E. saligna* to 48.0% for *E. citriodora*. In general, the strength characteristics of the bleached pulp followed the pattern of the unbleached pulp, the bleached pulp having tensile and bursting strengths about 10% lower, and a tearing strength about 15% higher, than unbleached pulp. The exceptions were pulp from *E. saligna* and *E. tereticornis*, where the bleached pulp had a tearing strength 10% lower than the unbleached pulp.

Soda and soda-anthraquinone pulping

Techniques for chemical recovery from the spent liquor of digestions using the soda-based process are less complex than those required for recovery of chemicals from sulphate liquors. Consequently, the cost of recovery plant is reduced and there is potential for smaller mills to be economically viable. The use of soda and soda-AQ processes also eliminate the environmental damage of sulphur emissions. To obtain data on the quality of pulps produced by soda-based processes, one soda and one soda-AQ digestion was made on each sample.

Initially, two soda and three soda-AQ digestions were made on *E. maculata* to identify conditions that would yield a pulp with approximately the same yield and kappa number as was obtained using the sulphate process with 15% active alkali. Following these orientating trials, soda digestions using 17.5% active alkali and soda-AQ using 15% active alkali and 0.1% anthraquinone were used for all samples. Details of digestion conditions and pulp qualities are recorded in the tables listed in the section on sulphate pulping.

The main differences between pulps prepared by the three processes were:

1 The soda process used the most alkali: 17.5% active alkali against 15% for the sulphate and soda-AQ processes.

2 The soda process yielded about 3% less pulp with a higher kappa number than either of the other processes.

3 To reduce the drainability of pulp to a value of 300 CSF, soda pulps required about 35%, and soda-AQ pulps about 10%, longer beating time than sulphate pulps.

4 The tensile strengths of soda pulps were 10 to 15% lower, and those of soda-AQ pulps 5 to 10% lower, than those of sulphate pulps.

5 The tensile energy absorbed (TEA) to breaking point by soda pulps was 20–40% lower and that of soda-AQ pulps 10–25% lower than values for sulphate pulps. The fact that the reduction in TEA is greater than the reduction in tensile strength indicates that the soda and soda-AQ pulps have lower stretch values (elasticity) than sulphate pulps.

6 The tearing strength of soda pulps was up to 15% lower, and that of soda-AQ pulps up to 5% lower and higher than, the tearing strength of sulphate pulps.

These findings show that sulphate and soda-AQ pulps were similar in yield and strength characteristics, whilst soda pulps had a lower yield and poorer strength characteristics. The findings are illustrated in Table 10 where, for each parameter, sulphate pulp is assigned a value of 100 and soda and soda-AQ pulps are given relative values.

Neutral sulphite semi-chemical pulping

One digestion was made on each species by the neutral sulphite semi-chemical process (NSSC). The same digestion conditions were used for all cooks: 12.5% sodium sulphite, 5% sodium bicarbonate, at 170°C with 2 h to reach and 2 h at temperature. The softened chips were disintegrated using a Sprout–Waldron 12-inch unpressurized laboratory refiner. The total yield from all species was about 70%. This pulp was screened, using a flat bed screen with 0.15 mm slits. The screen rejects were, in several cases, rather high. This was due to the difficulty of completing the disintegration of small batches of pulp in a laboratory refiner. The screened pulp had a drainability value of between 530 and 680 CSF. The screened pulps were beaten in a valley beater. Details of pulp yields and properties are reported in Table 11.

The strength characteristics of the NSSC pulps were lower than those of sulphate pulps: this was expected of high-yield pulps. However, the pulps should be suitable for use in packaging boards, such as corrugated boards. The main strength characteristics were about 70% of those of sulphate pulps, and this indicates that NSSC pulps could be used as partial substitutes for sulphate pulps in lower grades of paper.

Chemi-refiner mechanical pulp

Chemi-refiner mechanical pulp (CRMP) is produced by a mild chemical treatment of chips followed by atmospheric refining. The aim is to produce a pulp with a yield of about 90% and strength characteristics suitable for use in newsprint.

Only one digestion was made, using *E. grandis*. Details of pulping conditions and pulp characteristics are given in Table 12. This digestion, using approximately 6.5% NaOH on dry wood, had a yield of 70%, indicating that the conditions, either of chemical concentration or digestion time or both, were too severe. The pulp was stronger than that required for newsprint. It seemed likely that with optimum digestion conditions a satisfactory CRMP pulp could be made.

Comparison with hardwood pulps

To assess the potential of these possible pulpwoods comparison was made with other hardwoods, some of which are used for industrial production. All of these woods have been pulped in ODNRI, using techniques identical with those used in this investigation. The data are reported in Table 13.

The yield and strength characteristics of the eucalypt pulps were similar to those of the hardwoods quoted, indicating that they are suitable for industrial use. The yield and quality of pulps were similar to values obtained in previous studies at ODNRI with samples of *Eucalyptus* spp. from Zambia (Palmer and Gibbs, 1977), Kenya (Palmer *et al.*, 1982), Uganda (Palmer and Gibbs, 1984) and Solomon Islands (Palmer *et al.*, 1989).

CONCLUSIONS

1 There was a wide difference in the average dimensions of trees of each species. The fastest-growing species, *E. saligna* and *E. tereticornis*, produced about four times the volume of wood produced by the slowest-growing, *E. cloeziana*.

2 All species had wood with densities suitable for use as pulpwood. The least dense wood, from *E. grandis*, had a density of 448 kg m^{-3}; the most dense, from *E. citriodora*, was 674 kg m^{-3}. There was little correlation between rate of growth and wood density.

3 Chemical analysis indicated that all the species were suitable for chemical pulping. There was a wide range of values, especially for lignin content which was between 19% for *E. citriodora* and 32% for *E. saligna*.

4 Fibres from all species were short (about 0.9 mm), slender, thin-walled and flexible. This indicated that papers would have good fibre-to-fibre bonding and good bursting and tensile strengths.

5 All of the species were pulped by the sulphate process. All yielded more than 45% of a bleachable grade of pulp, with satisfactory strength characteristics. On the basis of pulp yield and all-round strength characteristics, *E. saligna* was the most promising species.

6 Pulps from all the species were bleached by a sequence of chlorine, alkali extraction, sodium hypochlorite and chlorine dioxide to a brightness of 87 to 89. The bleached pulps were a little weaker than the unbleached pulps but had adequate strength for printing and writing papers.

7 Higher concentrations of chemical were necessary using the soda process than the sulphate process to obtain pulps with the same kappa number (residual lignin content). The soda pulps needed more energy to beat and were much weaker than sulphate pulps. Consequently, soda pulping is unlikely to be economically viable.

8 Soda-anthraquinone pulping gave similar yields of pulp with the same kappa number as the sulphate process when using the same chemical dosage. The soda-AQ pulps were marginally weaker but could be used for the same products as sulphate pulps.

9 Neutral sulphite semi-chemical pulps were prepared from all species with a yield of about 70%. These pulps had strength characteristics suitable for use in packing boards and as a partial substitute for sulphate pulps in lower grades of paper.

10 Chemi-refiner mechanical pulp was made from *E. grandis*. Although optimum digestion conditions were not determined, the results were sufficiently promising to indicate that a newsprint grade of pulp could be made by this process.

11 As all the species yielded satisfactory pulp, the selection of preferred species to grow in Malawi for pulpwood will be based on yield of wood. Precise data on rate of growth were not available, but using the dimensions and wood density of trees in the samples, the two species producing most wood per unit of area were *E. tereticornis* and *E. saligna*. The other species, listed here in apparent order of wood production, *E. citriodora, E. maidenii,*

E. camaldulensis, E. cloeziana and *E. maculata*, all yielded less than half the weight of wood produced by the preferred species. *E. grandis* was not considered in the above estimate as data on the dimensions of trees in the sample were not available, but the diameter of logs measured after arrival in the UK, combined with the low wood density, did not indicate that it would compete with the preferred species.

12 Further investigations should be concentrated on coppice crops from the fastest-growing species to check changes in wood yield and pulp yield and properties at successive harvestings.

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Table 1

Tree dimensions, bark content and wood density

Species	Age, years	Height, m		Bole to 8 cm diam., m		Diameter, bh, ob, cm		Bark, % by volume		Bark, % by weight		Density, kg m^{-3}	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
E. camaldulensis	9	18.6	15.7–20.5	7.6	6–10	15.1	13.0–20.0	28	25–32	17	14–20	534	498–588
E. citriodora	9	20.6	16.9–25.2	10.3	5–16	15.9	11.0–21.0	27	26–30	–	–	674	614–740
E. cloeziana	9	13.5	9.6–17.3	6.4	3–10	13.9	10.0–17.0	25	22–30	–	–	598	560–631
E. grandis	9	–	–	–	–	14*	–	13	10–15	16	12–20	448	391–506
E. maculata	8	14.2	10.4–17.2	6.4	5–10.5	13.6	12.0–17.0	24	17–27	–	–	609	568–667
E. maidenii	9	18.2	16.5–19.2	9.2	8–11	14.8	14.0–17.0	27	24–30	17	13–19	615	558–689
E. saligna	8	21.7	16.0–26.6	15.0	9–20	22.0	16.0–30.0	22	19–27	–	–	552	484–624
E. tereticornis	8	22.9	19.6–26.7	14.5	10–20	19.3	16.0–24.0	22	17–28	–	–	643	615–674

Note: The values for height and diameter are measurements made by the Malawi Forest Department and recorded in field sheets. The field sheets for *E. grandis* were lost in transit: the mean diameter (*) was calculated from measurements of girth made on arrival in the UK

Table 2

Chemical composition

Species	Cold-water solubles	Hot-water solubles	1% NaOH solubles	Ethanol–benzene solubles	Total solubles	Lignin	Holo–cellulose	Alpha–cellulose	Pentosans	Ash	Silica
E. camaldulensis	4.6	4.4	17.2	1.6	5.9	26.8	70.5	42.8	14.2	0.9	0.2
E. citriodora	3.4	3.2	15.7	2.4	5.0	18.9	76.3	49.2	16.7	0.7	0.2
E. cloeziana	5.0	5.1	14.9	1.3	6.3	26.0	71.7	44.6	14.8	0.2	neg
E. grandis	4.2	4.2	17.5	2.2	6.3	27.0	69.6	42.0	16.1	0.4	0.1
E. maculata	3.2	3.2	17.3	1.2	4.1	20.6	75.4	44.7	17.5	0.7	0.2
E. maidenii	3.8	3.8	16.9	1.5	5.2	23.4	71.7	41.8	17.2	0.6	0.2
E. saligna	3.4	4.1	19.5	2.1	5.0	31.8	73.1	42.8	12.6	0.4	neg
E. tereticornis	2.9	3.4	15.1	1.0	4.6	30.4	73.4	47.3	11.4	0.5	neg

Notes: All values expressed as % oven-dry solubles or components on oven-dry unextracted sample
Total solubles = quantity dissolved in successive application of ethanol–benzene, ethanol and water
neg = less than 0.05%

Table 3

Fibre dimensions

	By projection		By classification, %						
Species	Width, µm	Wall thickness, µm	Passed aperture, µm Retained on aperture, µm	 595	595 420	420 210	210 74	 74*	Calculated fibre length, mm†
E. camaldulensis	13.9 (0.28)‡	2.8 (0.06)		0.8	36.3	46.1	8.3	8.5	0.88
E. citriodora	16.4 (0.39)	3.8 (0.09)		18.7	39.1	30.4	5.8	6.0	0.95
E. cloeziana	17.2 (0.28)	3.5 (0.08)		3.0	35.6	47.1	9.0	5.3	0.90
E. grandis	16.3 (0.30)	2.8 (0.06)		1.3	38.9	43.8	7.5	8.5	0.89
E. maculata	14.8 (0.30)	3.4 (0.07)		1.9	40.9	40.8	7.8	8.6	0.89
E. maidenii	14.4 (0.29)	3.5 (0.08)		1.0	47.1	36.9	7.1	7.9	0.89
E. saligna	16.2 (0.25)	3.5 (0.08)		6.3	38.4	39.7	8.0	7.6	0.90
E. tereticornis	13.8 (0.19)	3.7 (0.08)		3.8	38.6	42.6	8.8	6.2	0.90

Notes: * By difference
† Calculated from the proportion in, and the known length of, fibres for each class
‡ Figures in brackets are the standard error of the mean for each determination

Table 4

Eucalyptus species: pulp yield and properties at constant sulphate digestion conditions

Species	*E. camaldulensis*	*E. citriodora*	*E. cloeziana*	*E. grandis*	*E. maculata*	*E. maidenii*	*E. saligna*	*E. tereticornis*
Cook number	443	450	462	447	296	459	511	520
Yield								
Oven-dry digested pulp on oven-dry wood, %	48.0	53.2	49.5	49.3	51.6	51.0	49.0	47.4
Oven-dry screened pulp on oven-dry wood, %	46.7	50.9	45.3	46.6	50.7	47.8	46.6	45.7
Oven-dry screenings on oven-dry digested pulp, %	2.8	4.5	8.5	5.5	1.8	6.2	4.8	3.6
Pulp characteristics								
Kappa number	33.3	28.8	36.3	37.9	26.6	31.2	30.1	29.6
Drainability, CSF	300	300	300	300	300	300	300	300
Beating, revs	3260	6240	5390	4400	5200	5660	6690	7640
Apparent density, g cm^{-3}	0.73	0.64	0.72	0.79	0.74	0.76	0.72	0.63
Tensile index, N m g^{-1}	101	87	89	114	99	114	109	92
Tensile energy absorption index, mJ g^{-1}	2460	1640	1930	2540	2140	3060	2550	1910
Tear index, mN m^2 g^{-1}	7.7	9.1	8.6	8.3	8.4	8.4	11.6	12.8
Burst index, kPa m^2 g^{-1}	5.8	4.8	5.1	7.0	5.8	6.9	6.3	5.1
Folding endurance, $\log_{10} n$	2.4	2.1	2.0	2.7	2.5	2.7	2.5	2.0
Air resistance, s	33	11	18	82	28	31	27	7

Note: Active alkali, 15%; sulphidity, 25%; temperature, 170°C; time 1 + 2 hours

Table 5

Eucalyptus species: bleaching conditions and bleached pulp properties

Species	*E. camaldulensis*	*E. citriodora*	*E. cloeziana*	*E. grandis*	*E. maculata*	*E. maidenii*	*E. saligna*	*E. tereticornis*
Cook number	445	449	461	448	295	460	512	521
Unbleached pulp								
Yield on oven-dry wood, %	45.3	50.6	46.4	46.7	50.1	47.7	45.3	45.6
Kappa number	27.1	22.7	28.1	28.9	22.3	24.1	24.3	23.6
Bleaching conditions								
1 Chlorination for 1 h at 20°C, pulp consistency, 3%								
Chlorine applied as Cl_2 on oven-dry unbleached pulp, %	7.5	6.1	7.9	8.1	5.9	6.5	6.6	6.4
Chlorine consumed as Cl_2 on oven-dry unbleached pulp, %	6.4	5.3	6.9	6.5	4.9	3.8	5.5	5.5
2 Alkaline extraction for 1 h at 60°C, pulp consistency, 6%								
NaOH on oven-dry unbleached pulp, %	3	3	3	3	3	3	3	3
3 Hypochlorite for 2 h at 35°C, pulp consistency, 6%								
NaOCl applied as available Cl_2 on oven-dry unbleached pulp, %	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
NaOCl consumed as available Cl_2 on oven-dry unbleached pulp, %	0.7	0.6	0.7	0.7	0.6	0.6	0.7	0.7
4 Chlorine dioxide for 3 h at 70°C, pulp consistency, 6%								
ClO_2 applied as Cl_2 equivalent on oven-dry unbleached pulp, %	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
ClO_2 consumed as Cl_2 equivalent on oven-dry unbleached pulp, %	2.4	2.1	2.3	2.3	2.3	2.3	2.4	2.2
Total chlorine applied as Cl_2 on oven-dry unbleached pulp, %	11.1	9.7	11.5	11.8	9.6	10.2	10.2	10.0
Total chlorine consumed as Cl_2 on oven-dry unbleached pulp, %	9.5	8.0	9.9	9.6	7.8	6.7	8.6	8.4
Yield of pulp								
Oven-dry bleached pulp on oven-dry unbleached pulp, %	94.1	94.9	93.8	94.0	95.4	94.1	94.8	95.1
Oven-dry bleached pulp on oven-dry wood, %	42.6	48.0	43.6	43.9	47.8	44.9	42.9	43.4
Pulp evaluation								
ISO brightness, unbeaten pulp, %	88	87	88	88	88	89	87	88
Specific scattering coefficient, unbeaten sheet, $cm^2\ g^{-1}$	640	410	490	600	495	570	540	530
Drainability, CSF	300	300	300	300	300	300	300	300
Beating, revs	5220	9450	10,000	6440	8920	7100	8000	10,370
Apparent density, $g\ cm^{-3}$	0.75	0.64	0.76	0.79	0.73	0.74	0.74	0.66
Tensile index, $N\ m\ g^{-1}$	86	77	77	99	88	93	90	81
Tensile energy absorption index, $mJ\ g^{-1}$	2080	1420	1910	2400	2020	2180	2060	1680
Tear index, $mN\ m^2\ g^{-1}$	8.4	11.9	9.0	9.7	11.0	9.3	10.0	11.3
Burst index, $kPa\ m^2\ g^{-1}$	5.1	4.0	4.3	5.6	4.8	5.4	5.3	4.5
Folding endurance, $\log_{10}n$	2.3	2.0	2.1	2.5	2.0	2.4	2.4	2.0
Air resistance, s	39	8	15	77	26	23	29	10
Opacity, %	80	74	72	77	74	75	76	78
Specific scattering coefficient, $cm^2\ g^{-1}$	385	305	270	330	300	330	310	360

Table 6

Digestion conditions, unbleached pulp yield and evaluation

	E. camaldulensis					*E. citriodora*				
Cook number	444	443	445	452	451	481	450	449	456	455
Type of digestion	Sulphate	Sulphate	Sulphate	Soda	Soda-AQ	Sulphate	Sulphate	Sulphate	Soda	Soda-AQ
Digestion conditions										
Active alkali as Na_2O on oven-dry wood, %	12.5	15	17.5	17.5	15	12.5	15	17.5	17.5	15
Sulphidity, %	25	25	25	–	–	25	25	25	–	–
Anthraquinone on oven-dry wood %	–	–	–	–	0.1	–	–	–	–	0.1
Liquor to oven-dry wood ratio	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C	170	170	170	170	170	170	170	170	170	170
Time to reach maximum temperature, h	1	1	1	1	1	1	1	1	1	1
Time at maximum temperature, h	2	2	2	2	2	2	2	2	2	2
Chemical consumption										
Active alkali consumed as Na_2O on oven-dry wood, %	11.7	13.6	15.2	15.0	13.7	11.4	13.3	14.2	14.3	13.3
Yield of pulp										
Oven-dry digested pulp on oven-dry wood, %	50.9	48.0	45.6	45.6	47.9	58.3	53.2	51.5	51.1	53.6
Oven-dry screened pulp on oven-dry wood, %	43.4	46.7	45.3	45.3	46.9	46.6	50.9	50.7	50.3	52.6
Oven-dry screenings on oven-dry digested pulp, %	14.6	2.8	0.6	0.6	2.1	19.1	4.5	1.6	1.9	3.0
Pulp evaluation										
Kappa number	44.5	33.3	27.1	33.7	29.6	36.6	28.8	22.7	26.5	27.1
Drainability, CSF	300	300	300	300	300	300	300	300	300	300
Beating, revs	3290	3260	3900	4290	4130	5230	6240	7150	7480	6900
Apparent density, g cm^{-3}	0.73	0.73	0.71	0.71	0.74	0.64	0.64	0.65	0.63	0.64
Tensile index, N m g^{-1}	102	101	95	84	94	86	87	83	73	83
Tensile energy absorption index, mJ g^{-1}	2440	2460	2100	1530	2010	1740	1640	1470	1120	1520
Tear index, mN m^2 g^{-1}	8.0	7.7	7.1	6.6	7.8	10.5	9.1	9.5	8.8	9.0
Burst index, kPa m^2 g^{-1}	6.3	5.8	5.6	4.5	5.8	4.7	4.8	4.6	3.9	4.5
Folding endurance, $\log_{10}n$*	2.6	2.4	2.2	1.9	2.2	2.0	2.1	2.0	1.7	1.9
Air resistance, s	32	33	40	25	37	13	11	11	9	10

Note: * n = number of double folds

Table 7

Digestion conditions, unbleached pulp yield and evaluation

	E. cloeziana					*E. grandis*				
Cook number	514	462	461	476	478	446	447	448	453	454
Type of digestion	Sulphate	Sulphate	Sulphate	Soda	Soda-AQ	Sulphate	Sulphate	Sulphate	Soda	Soda-AQ
Digestion conditions										
Active alkali as Na_2O on oven-dry wood, %	12.5	15	17.5	17.5	15	12.5	15	17.5	17.5	15
Sulphidity, %	25	25	25	–	–	25	25	25	–	–
Anthraquinone on oven-dry wood %	–	–	–	–	0.1	–	–	–	–	0.1
Liquor to oven-dry wood ratio	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C	170	170	170	170	170	170	170	170	170	170
Time to reach maximum temperature, h	1	1	1	1	1	1	1	1	1	1
Time at maximum temperature, h	2	2	2	2	2	2	2	2	2	2
Chemical consumption										
Active alkali consumed as Na_2O on oven-dry wood, %	11.9	13.8	15.5	15.1	13.9	11.9	13.7	15.4	15.0	14.0
Yield of pulp										
Oven-dry digested pulp on oven-dry wood, %	53.4	49.5	47.4	48.0	50.5	54.1	49.3	47.4	47.1	48.8
Oven-dry screenings on oven-dry wood, %	38.7	45.3	46.4	44.1	45.5	41.2	46.6	46.1	46.1	46.8
Oven-dry screenings on oven-dry digested pulp, %	27.5	8.5	2.1	8.1	10.0	23.9	5.5	1.5	2.0	4.2
Pulp evaluation										
Kappa number	52.5	36.3	28.1	44.8	36.9	60.9	37.9	28.9	39.5	34.6
Drainability, CSF	300	300	300	300	300	300	300	300	300	300
Beating, revs	7100	5390	6040	8170	6260	3540	4400	4500	6290	4600
Apparent density, g cm^{-3}	0.70	0.72	0.71	0.68	0.69	0.84	0.79	0.79	0.76	0.79
Tensile index, N m g^{-1}	86	89	87	74	83	113	114	109	98	109
Tensile energy absorption index, mJ g^{-1}	1960	1930	1780	1340	1500	2590	2540	2400	2080	2350
Tear index, mN m^2 g^{-1}	9.9	8.6	8.7	8.4	9.1	7.8	8.3	8.3	7.8	8.2
Burst index, kPa m^2 g^{-1}	4.9	5.1	4.8	3.9	4.5	6.7	7.0	6.1	5.6	6.3
Folding endurance, $\log_{10}n$*	2.3	2.0	2.0	1.7	2.0	2.5	2.7	2.4	2.5	2.5
Air resistance, s	11	18	26	9	11	60	82	73	60	86

Note: * n = number of double folds

Table 8

Digestion conditions, unbleached pulp yield and evaluation

	E. maculata								*E. maidenii*				
Cook number	297	296	295	299	276	301	300	298	482	459	460	477	480
Type of digestion	Sulphate	Sulphate	Sulphate	Soda	Soda	Soda-AQ	Soda-AQ	Soda-AQ	Sulphate	Sulphate	Sulphate	Soda	Soda-AQ
Digestion conditions													
Active alkali as Na_2O on oven-dry wood, %	12.5	15	17.5	15	17.5	12.5	15	15	12.5	15	17.5	17.5	15
Sulphidity, %	25	25	25	–	–	–	–	–	25	25	25	–	–
Anthraquinone on oven-dry wood %	–	–	–	–	–	0.1	0.1	0.1	–	–	–	–	0.1
Liquor to oven-dry wood ratio	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C	170	170	170	170	170	170	170	170	170	170	170	170	170
Time to reach maximum temperature, h	1	1	1	1	1	1	1	1	1	1	1	1	1
Time at maximum temperature, h	2	2	2	2	2	2	1	2	2	2	2	2	2
Chemical consumption													
Active alkali consumed as Na_2O on oven-dry wood, %	11.6	13.4	14.5	13.0	14.2	11.7	12.4	13.4	11.7	13.7	15.4	14.9	13.6
Yield of pulp													
Oven-dry digested pulp on oven-dry wood, %	55.9	51.6	50.2	51.8	49.6	55.0	53.8	51.1	54.4	51.0	47.9	47.5	50.1
Oven-dry screened pulp on oven-dry wood, %	47.7	50.7	50.1	48.6	49.4	46.7	49.9	50.6	40.7	47.8	47.7	46.6	47.1
Oven-dry screenings on oven-dry digested pulp, %	14.7	1.8	0.3	6.2	0.4	15.0	7.3	1.0	25.2	6.2	0.4	2.1	6.0
Pulp evaluation													
Kappa number	37.8	26.6	22.3	37.7	27.6	34.5	30.6	24.0	43.0	31.2	24.1	32.2	30.6
Drainability, CSF	300	300	300	300	300	300	300	300	300	300	300	300	300
Beating, revs	4200	5200	6750	7233	6420	5340	5731	5417	5760	5660	5960	7460	5830
Apparent density, g cm^{-3}	0.73	0.74	0.74	0.70	0.72	0.71	0.70	0.71	0.74	0.76	0.76	0.73	0.73
Tensile index, N m g^{-1}	102	99	101	92	90	101	96	93	114	114	106	101	110
Tensile energy absorption index, mJ g^{-1}	2120	2140	2190	1730	1710	1830	1740	1740	2660	3060	2430	2160	2330
Tear index, mN m^2 g^{-1}	7.9	8.4	9.2	8.1	8.0	9.0	9.6	8.9	8.7	8.4	8.4	8.3	8.8
Burst index, kPa m^2 g^{-1}	5.8	5.8	5.6	5.0	4.8	5.4	5.0	5.0	6.8	6.9	6.3	5.7	6.4
Folding endurance, $\log_{10}n$*	2.5	2.5	2.1	2.1	2.1	2.1	2.0	1.9	2.5	2.7	2.5	2.2	2.4
Air resistance, s	96	28	25	16	16	16	14	15	46	31	30	19	20

Note: * n = number of double folds

Table 9

Digestion conditions, unbleached pulp yield and evaluation

	E. saligna					*E. tereticornis*				
Cook number	513	511	512	515	516	519	520	521	522	523
Type of digestion	Sulphate	Sulphate	Sulphate	Soda	Soda-AQ	Sulphate	Sulphate	Sulphate	Soda	Soda-AQ
Digestion conditions										
Active alkali as Na_2O on oven-dry wood, %	12.5	15	17.5	17.5	15	12.5	15	17.5	17.5	15
Sulphidity, %	25	25	25	–	–	25	25	25	–	–
Anthraquinone on oven-dry wood %	–	–	–	–	0.1	–	–	–	–	0.1
Liquor to oven-dry wood ratio	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C	170	170	170	170	170	170	170	170	170	170
Time to reach maximum temperature, h	1	1	1	1	1	1	1	1	1	1
Time at maximum temperature, h	2	2	2	2	2	2	2	2	2	2
Chemical consumption										
Active alkali consumed as Na_2O on oven-dry wood, %	11.7	13.7	15.5	14.8	13.9	11.5	13.5	14.5	14.5	13.3
Yield of pulp										
Oven-dry digested pulp on oven-dry wood, %	52.3	49.0	45.7	46.6	48.3	51.3	47.4	45.9	45.7	47.6
Oven-dry screened pulp on oven-dry wood, %	43.6	46.6	45.3	45.9	46.9	43.9	45.7	45.6	45.0	45.8
Oven-dry screenings on oven-dry digested pulp, %	16.5	4.8	0.8	1.6	2.8	14.4	3.6	0.6	1.5	3.9
Pulp evaluation										
Kappa number	42.6	30.1	24.3	35.1	29.0	41.1	29.6	23.6	33.4	31.8
Drainability, CSF	300	300	300	300	300	300	300	300	300	300
Beating, revs	5910	6690	7620	9840	6750	5750	7640	8760	9990	8320
Apparent density, g cm^{-3}	0.73	0.72	0.73	0.71	0.70	0.63	0.63	0.65	0.62	0.62
Tensile index, N m g^{-1}	109	109	100	92	95	98	92	89	78	85
Tensile energy absorption index, mJ g^{-1}	2640	2550	2260	1980	1920	2130	1910	1800	1460	1760
Tear index, mN m^2 g^{-1}	10.9	11.6	10.7	10.6	11.4	11.9	12.8	12.3	10.6	11.7
Burst index, kPa m^2 g^{-1}	6.3	6.3	5.8	4.8	5.2	5.5	5.1	5.0	4.0	4.6
Folding endurance, $\log_{10} n$*	2.8	2.5	2.5	2.0	2.1	2.2	2.0	2.0	1.6	1.9
Air resistance, s	31	27	33	22	23	7	7	9	7	7

Note: * n = number of double folds

Table 10

Comparison of sulphate, soda and soda–anthraquinone pulps

Each parameter stated on the basis that value for sulphate pulp for the same species = 100

	Total yield		Screened yield		Kappa number		Beating, revs		Sheet density		Tensile strength		Tensile energy absorbed		Bursting strength		Tearing strength	
	Soda	Soda–AQ	Soda	Soda–AQ	Soda	Soda–AQ	Soda	Soda–AQ	Soda	Soda–AQ	Soda	Soda–AQ	Soda	Soda–AQ	Soda	Soda–AQ	Soda	Soda–AQ
E. camaldulensis	95	100	97	100	101	89	132	127	97	101	83	93	63	82	76	100	86	101
E. citriodora	96	101	99	103	92	94	120	111	98	100	84	95	68	93	81	94	97	99
E. cloeziana	97	102	97	100	123	102	152	116	94	96	83	93	69	78	76	88	98	106
E. grandis	96	99	99	100	104	91	143	105	96	100	86	96	82	93	80	90	94	99
E. maculata	96	99	97	100	104	90	123	104	97	96	91	94	80	81	83	86	95	106
E. maidenii	93	98	97	99	103	98	132	103	96	96	88	96	71	76	83	93	99	105
E. saligna	95	99	98	101	117	96	147	101	99	97	84	87	78	75	76	83	91	98
E. tereticornis	96	100	98	100	113	107	131	109	98	98	84	92	76	92	78	90	83	91

Notes: Sulphate digestions: 15% active alkali, 25% sulphidity, 170°C, 1+2 h
Soda digestions: 17.5% active alkali, 170°C, 1+2 h
Soda–anthraquinone digestions: 15% active alkali, 0.1% anthraquinone, 170°C, 1+2 h

Table 11

Eucalyptus species: pulp yield and properties at constant neutral sulphite semi-chemical conditions

Species	*E. camaldulensis*		*E. citriodora*		*E. cloeziana*		*E. grandis*		*E. maculata*		*E. maidenii*		*E. saligna*		*E. tereticornis*	
Cook number	537		542		543		541		540		544		545		547	
pH of residual digestion liquor	9.2		8.7		9.2		9.1		8.5		9.0		8.8		9.1	
Yield of pulp																
Oven-dry digested pulp on oven-dry wood, %	71.3		67.4		69.5		69.1		68.0		65.4		68.1		70.0	
Oven-dry screened pulp on oven-dry wood, %	69.0		56.7		57.4		66.1		65.5		61.6		60.4		55.7	
Pulp evaluation																
Drainability, CSF	500	300	500	300	500	300	500	300	500	300	500	300	500	300	500	300
Beating time, min	9	30	12	29	18	38	1	26	7	26	1	19	12	34	21	43
Apparent density, g cm^{-3}	0.51	0.61	0.48	0.56	0.47	0.55	0.48	0.63	0.53	0.63	0.48	0.60	0.49	0.58	0.46	0.55
Tensile index, N m g^{-1}	53	72	40	59	42	57	48	80	45	73	43	71	48	69	46	62
Tensile energy absorption index, mJ g^{-1}	570	1100	340	780	350	720	420	1140	390	970	460	950	450	980	420	870
Tear index, mN m^2 g^{-1}	6.2	6.0	5.7	7.2	4.5	5.3	6.0	6.3	5.7	6.8	6.1	6.6	6.7	6.4	5.3	5.2
Burst index, kPa m^2 g^{-1}	2.2	3.6	1.5	3.0	1.5	2.4	1.8	3.8	1.8	3.4	1.7	3.5	2.1	3.5	1.8	2.8
Folding endurance, $\log_{10} n$	1.0	1.6	0.6	1.3	0.6	1.2	0.9	1.9	0.7	1.6	0.8	1.5	0.8	1.5	0.6	1.2
Air resistance, s	3.0	26	1.2	11	0.7	5.1	2.6	48	2.5	28	1.5	19	1.2	14	0.7	6

Note: Sodium sulphite 12.5%, sodium bicarbonate 5%, temperature 170°C, time 2+2 h

Table 12

E. grandis: chemi–thermal mechanical pulp digestion conditions, pulp yield and properties

Cook number	573	
Active alkali as Na_2O on oven-dry wood, %	5	
Maximum temperature, °C	170	
Time to reach maximum temperature, h	1	
Time at maximum temperature, h	1	
Yield of pulp		
Oven-dry refined pulp on oven-dry wood, %	68.3	
Oven-dry screened pulp on oven-dry wood, %	53.3	
Pulp evaluation		
Drainability, CSF	500	300
Beating time, min	12	27
Apparent density, g cm^{-3}	0.43	0.50
Tensile index, N m g^{-1}	32	49
Tensile energy absorption index, mJ g^{-1}	270	620
Tear index, mN m^2 g^{-1}	4.0	4.4
Burst index, kPa m^2 g^{-1}	1.3	2.2
Folding endurance, $\log_{10}n$	0.2	0.9
Air resistance, s	0.7	7.0

Table 13

Hardwoods for comparison

Species	Mixed hardwoods, Southern USA		*Fagus sylvatica*	*Eucalyptus saligna* Grown in Kenya	*Eucalyptus camaldulensis* Grown in Kenya
Cook number	MK60	MK313	MK88	MK80	MK318
Digestion conditions					
Active alkali as Na_2O on oven-dry wood, %	15	15	15	15	15
Sulphidity, %	25	25	25	25	25
Liquor to oven-dry wood ratio	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C	170	170	170	170	170
Time to reach maximum temperature, h	1	2	1	1	1
Time at maximum temperature, h	2	2	2	2	2
Chemical consumption					
Active alkali consumed as Na_2O on oven-dry wood, %	13.2	12.6	13.0	12.7	13.2
Yield of pulp					
Oven-dry digested pulp on oven-dry wood, %	49.4	45.4	49.8	51.7	46.6
Oven-dry screened pulp on oven-dry wood, %	47.8	43.4	45.2	51.0	45.7
Oven-dry screenings on oven-dry digested pulp, %	3.2	4.5	9.2	1.4	1.8
Pulp evaluation					
Kappa number	27.6	23.8	23.2	23.7	28.3
Drainability, CSF	300	300	300	300	300
Beating, revs	7500	8300	8500	7600	5000
Apparent density, g cm^{-3}	0.66	0.68	0.67	0.67	0.68
Tensile index, N m g^{-1}	106	103	95	111	105
Tear index, mN m^2 g^{-1}	11.2	10.8	8.8	10.0	9.7
Burst index, kPa m^2 g^{-1}	7.1	6.7	6.2	7.4	6.5

Appendix

This appendix consists of a number of Tables, listed below, which give full data which were summarized in the Tables in the body of the report.

Table

Table	Species	Content
I	*Eucalyptus camaldulensis*	Tree dimensions and bark content
II	*Eucalyptus citriodora*	
III	*Eucalyptus cloeziana*	
IV	*Eucalyptus grandis*	
V	*Eucalyptus maculata*	
VI	*Eucalyptus maidenii*	
VII	*Eucalyptus saligna*	
VIII	*Eucalyptus tereticornis*	
IX	*E. camaldulensis*	Wood density
X	*E. citriodora*	
XI	*E. cloeziana*	
XII	*E. grandis*	
XIII	*E. maculata*	
XIV	*E. maidenii*	
XV	*E. saligna*	
XVI	*E. tereticornis*	
XVII	*E. camaldulensis*	Pulp evaluation
XVIII	*E. citriodora*	
XIX	*E. cloeziana*	
XX	*E. grandis*	
XXI	*E. maculata*	
XXII	*E. maidenii*	
XXIII	*E. saligna*	
XXIV	*E. tereticornis*	
XXV	Neutral sulphite semi-chemical cooks: pulp evaluation valley beates	
XXVI	*E. grandis:* chemi-thermal mechanical pulp – pulp evaluation valley beates	

Table I

E. camaldulensis: tree dimensions and bark content

Age, years	Tree number	Position on site	Height, m		Diameter, bh, cm		Diameter, ob at sampling points, cm					Bark content, %	
			To 8 cm diam.	Total	ob	ub	10	30	50	70	90	By volume	By weight
9	4	Slope	6	17.0	14.0	11.7	16	13	12	11	10	31	15
	5	Slope	8	17.9	13.0	11.0	14	13	11	11	10	26	17
	6	Slope	6	15.7	13.0	11.2	13	12	11	10	10	25	20
	7	Valley	10	17.1	20.0	16.2	20	17	15	13	11	30	14
	8	Valley	9	18.3	16.0	13.7	16	14	13	11	10	28	16
	9	Valley	6	16.2	13.0	10.5	14	12	11	10	10	32	18
	10	Slope	8	20.5	17.0	14.7	17	14	12	11	11	26	17
	Mean		7.6	18.6	15.1	12.7						28	17

Notes: All dimensions taken from field sheets made by Malawi Forest Department
bh = breast height
ob = over bark
ub = under bark
Bark content by volume calculated from $[(d_o^2 - d_u^2)/d_o^2] \times 100$
Where d_o = diameter over bark
d_u = diameter under bark

Table II

E. citriodora: tree dimensions and bark content

Age, years	Tree number	Position on site	Height, m		Diameter, bh, cm		Diameter, ob at sampling points, cm					Bark content, % by volume
			To 8 cm diam.	Total	ob	ub	10	30	50	70	90	
9	1	Slope	5	16.9	12.0	10.5	13	12	11	10	9	28
	2	Slope	9	18.0	13.0	11.1	14	12	10	10	10	30
	3	Ridge	10	21.5	17.0	14.1	18	16	14	12	10	29
	4	Slope	13	23.7	20.0	17.9	20	18	13	12	10	26
	5	Slope	12	21.2	16.0	14.1	16	14	12	11	10	27
	6	Slope	13	22.1	21.0	17.9	20	15	13	12	10	26
	7	Valley	14	22.3	17.0	15.4	17	14	12	11	10	27
	8	Ridge	16	25.2	20.0	18.0	20	16	14	12	11	26
	9	Slope	5	17.3	11.0	9.5	13	11	11	11	10	28
	10	Slope	6	17.6	12.0	10.9	14	11	10	10	10	26
	Mean		10.3	20.6	15.9	13.9						27

Notes: All dimensions taken from field sheets made by Malawi Forest Department
bh = breast height
ob = over bark
ub = under bark
Bark content by volume calculated from $[(d_o^2 - d_u^2)/d_o^2] \times 100$
Where d_o = diameter over bark
d_u = diameter under bark
Bark content by weight not determined because bark separated from discs in transit and could not be recovered quantitatively

Table III

E. cloeziana: tree dimensions and bark content

Age, years	Tree number	Position on site	Height, m: To 8 cm diam.	Height, m: Total	Diameter, bh, cm: ob	Diameter, bh, cm: ub	Diameter, ob at sampling points, cm: 10	30	50	70	90	Bark content, % by volume
9	1	Ridge	6	14.3	14.0	12.1	15	13	12	11	10	26
	2	Slope	7	13.2	14.0	12.0	15	14	12	11	10	30
	3	Ridge	3	10.1	10.0	9.1	12	11	10	10	9	22
	4	Ridge	9	15.7	16.0	14.3	18	15	13	11	10	28
	5	Slope	10	17.3	16.0	14.4	16	15	13	13	10	23
	6	Ridge	5	12.1	14.0	12.3	15	14	12	11	11	26
	7	Ridge	5	13.0	12.0	10.5	14	12	11	10	10	22
	8	Slope	3	9.6	12.0	10.1	14	13	12	11	9	27
	9	Slope	8	13.2	17.0	15.0	19	17	14	13	10	25
	10	Slope	8	16.7	14.0	12.4	16	15	13	11	10	25
	Mean		6.4	13.5	13.9	12.2						25

Notes: All dimensions taken from field sheets made by Malawi Forest Department
bh = breast height
ob = over bark
ub = under bark
Bark content by volume calculated from $[(d_o^2 - d_u^2)/d_o^2] \times 100$
Where d_o = diameter over bark
d_u = diameter under bark
Bark content by weight not determined because bark separated from discs in transit and could not be recovered quantitatively

Table IV

E. grandis: tree dimensions and bark content

Age, years	Tree number	Girth, ub at sampling points, cm					Bark content, %	
		10	30	50	70	90	By volume	By weight
9	1	42.0	39.7	35.9	33.3	26.9		19
	2	45.8	44.9	36.7	34.1	28.9		12
	3	48.2	43.2	37.4	35.4	34.2		17
	4	36.5	33.8	31.9	33.4	28.0	12	15
	5	45.6	41.9	36.9	32.3	29.4	10	14
	6	36.8	33.7	31.4	30.7	25.5	12	12
	7	44.3	41.7	41.1	32.5	27.9	14	17
	8	32.2	29.1	27.1	26.6	25.6	12	15
	9	32.3	28.2	26.5	24.6	23.8	15	20
	10	44.9	40.8	41.6	33.6	29.5	13	14
	Mean						13	16

Notes: Field notes with details of dimensions lost in transit
Girth underbark (ub) of all samples and girth overbark (ob) for most, were measured on arrival in UK
Where possible the bark content by volume was calculated using the relationship $[(g_o^2 - g_u^2)/g_o^2] \times 100$

Table V

E. maculata: tree dimensions and bark content

Age, years	Tree number	Position on site	Height, m: To 8 cm diam.	Height, m: Total	Diameter, bh, cm: ob	Diameter, bh, cm: ub	Diameter, ob at sampling points, cm: 10	30	50	70	90	Bark content, % by volume
8	1	Slope	7	12.4	15.0	13.8	16	14	13	11	10	—
	2	Slope	5	13.8	13.0	11.9	14	13	12	11	9	27
	3	Slope	7	15.5	14.0	11.6	16	14	13	11	10	26
	4	Ridge	6	15.0	12.0	11.0	13	12	10	10	9	24
	5	Ridge	8	14.2	14.0	12.3	15	14	12	12	10	23
	6	Ridge	6	16.0	12.0	10.8	13	12	10	10	9	19
	7	Ridge	10.5	17.2	17.0	14.8	17	14	13	12	10	22
	8	Slope	5	13.3	13.0	11.6	14	12	11	10	9	17
	9	Slope	4	10.4	13.0	11.9	15	13	12	12	11	27
	10	Slope	5	13.9	13.0	11.6	15	13	13	12	12	27
	Mean		6.4	14.2	13.6	12.1						24

Notes: All dimensions taken from field sheets made by Malawi Forest Department
bh = breast height
ob = over bark
ub = under bark
Bark content by volume calculated from $\left[(d_o^2 - d_u^2)/d_o^2\right] \times 100$
Where d_o = diameter over bark
d_u = diameter under bark
Bark content by weight not determined because bark separated from discs in transit and could not be recovered quantitatively
Discs from Tree 1 were not received

Table VI

E. maidenii: tree dimensions and bark content

Age, years	Tree number	Position on site	Height, m		Diameter, bh, cm		Diameter, ob at sampling points, cm					Bark content, %	
			To 8 cm diam.	Total	ob	ub	10	30	50	70	90	By volume	By weight
9	2	Slope	11	19.2	17.0	14.5	18	15	14	12	10	30	15
	3	Slope	9	18.4	14.0	12.2	14	12	11	10	10	29	18
	6	Ridge	10	18.4	14.0	11.8	14	13	12	11	10	29	15
	7	Ridge	8	16.5	14.0	12.4	14	13	12	11	10	25	13
	8	–	–	–	–	–	–	–	–	–	–	–	19
	10	Valley	8	18.5	15.0	12.7	15	14	12	12	11	24	19
	Mean		9.2	18.2	14.8	12.7						27	17

Notes: All dimensions taken from field sheets made by Malawi Forest Department
bh = breast height
ob = over bark
ub = under bark
Bark content by volume calculated from $\left[(d_o^2 - d_u^2)/d_o^2\right] \times 100$
Where d_o = diameter over bark
d_u = diameter under bark

Table VII

E. saligna: tree dimensions and bark content

Age, years	Tree number	Height, m		Diameter, bh, cm		Diameter, ob at sampling points, cm					Bark content, % by volume
		To 8 cm diam.	Total	ob	ub	10	30	50	70	90	
8	1	12.8	18.0	20.0	17.5	19	17	15	12	10	20
	2	18.6	25.7	22.0	19.2	21	19	17	15	11	22
	3	17.4	23.0	30.0	26.8	30	26	18	16	13	19
	4	19.7	26.6	24.0	21.4	24	20	19	15	11	20
	5	10.7	19.8	17.0	14.8	18	15	14	10	9	24
	6	16.4	24.0	23.0	20.2	22	19	18	16	10	21
	7	9.0	16.0	16.0	13.8	16	14	12	13	9	23
	8	16.0	22.0	19.0	16.2	19	17	15	13	10	27
	9	15.0	21.6	22.0	19.6	22	20	14	12	10	24
	10	14.2	20.7	27.0	24.0	27	22	19	14	10	24
	Mean	15.0	21.7	22.0	19.4						22

Notes: All dimensions taken from field sheets made by Malawi Forest Department
bh = breast height
ob = over bark
ub = under bark
Bark content by volume calculated from $[(d_o^2 - d_u^2)/d_o^2] \times 100$
Where d_o = diameter over bark
d_u = diameter under bark
Bark content by weight not determined because bark separated from discs in transit and could not be recovered quantitatively

Table VIII

E. tereticornis: tree dimensions and bark content

Age, years	Tree number	Height, m: To 8 cm diam.	Height, m: Total	Diameter, bh, cm: ob	Diameter, bh, cm: ub	Diameter, ob at sampling points, cm: 10	30	50	70	90	Bark content, % by volume
8	1	10.4	21.7	20.0	19.8	21	14	12	12	10	17
	2	10.6	19.7	17.0	14.8	17	14	12	11	10	21
	3	11.5	19.6	16.0	14.2	16	13	12	11	10	23
	4	14.4	22.1	19.0	16.0	19	16	14	12	10	28
	5	13.9	21.9	19.0	16.0	19	15	14	12	10	24
	6	19.5	26.7	24.0	21.4	23	19	16	14	10	19
	7	11.5	21.0	18.0	15.0	18	14	12	11	10	23
	8	19.0	26.3	20.0	17.6	20	16	13	11	10	22
	9	16.7	25.5	20.0	16.4	19	16	14	12	10	21
	10	18.0	24.6	22.0	18.2	19	17	15	12	10	18
	Mean	14.5	22.9	19.3	16.9						22

Notes: All dimensions taken from field sheets made by Malawi Forest Department
bh = breast height
ob = over bark
ub = under bark
Bark content by volume calculated from $\left[(d_o^2 - d_u^2)/d_o^2\right] \times 100$
Where d_o = diameter over bark
d_u = diameter under bark
Bark content by weight not determined because bark separated from discs in transit and could not be recovered quantitatively

Table IX

E. camaldulensis: wood density

Tree number	Density at sampling points, $kg\ m^{-3}$ 10	30	50	70	90	Tree mean
4	575	517	522	520	540	539
5	504	479	513	496	495	498
6	679	544	544	573	534	588
7	494	494	513	522	521	506
8	544	534	526	547	578	543
9	566	540	530	533	508	540
10	590	529	541	535	504	545
Site mean						534

Table X

E. citriodora: wood density

Tree number	Density at sampling points, $kg\ m^{-3}$ 10	30	50	70	90	Tree mean
1	633	612	613	612	585	614
2	686	642	581	627	684	650
3	699	688	675	719	675	692
4	776	743	710	725	695	740
5	692	666	660	653	643	667
6	689	663	656	659	650	670
7	672	650	651	636	642	655
8	741	693	671	674	698	703
9	705	654	636	657	650	662
10	653	619	599	593	595	616
Site mean						674

Table XI

E. cloeziana: wood density

Tree density	Density at sampling points, $kg\ m^{-3}$ 10	30	50	70	90	Tree mean
1	595	608	602	607	594	601
2	626	637	628	639	622	631
3	600	582	579	598	597	591
4	602	616	631	620	640	617
5	611	604	595	625	618	609
6	549	557	556	553	599	560
7	611	566	568	564	580	581
8	628	627	623	657	606	629
9	529	556	570	621	582	562
10	599	599	612	622	673	614
Site mean						598

Table XII

E. grandis: wood density

Tree number	Density at sampling points, kg m^{-3} 10	30	50	70	90	Tree mean
1	474	450	430	439	439	449
2	498	524	424	474	441	480
3	475	467	458	465	535	477
4	428	386	401	416	483	420
5	392	400	389	369	397	391
6	462	430	442	484	451	454
7	465	455	456	414	430	449
8	468	421	367	359	396	409
9	431	384	383	365	367	391
10	525	469	531	471	529	506
Site mean						448

Table XIII

E. maculata: wood density

Tree number	Density at sampling points, kg m^{-3} 10	30	50	70	90	Tree mean
2	637	588	564	552	551	584
3	693	653	639	621	621	654
4	703	657	631	649	675	667
5	596	567	559	552	539	568
6	645	600	603	645	606	620
7	621	579	600	574	607	598
8	673	638	601	591	584	626
9	657	588	570	568	575	597
10	620	578	605	579	591	596
Site mean						609

Table XIV

E. maidenii: wood density

Tree number	Density at sampling points, kg m^{-3} 10	30	50	70	90	Tree mean
2	685	695	682	694	694	689
3	561	583	615	653	608	598
6	595	625	613	611	646	615
7	527	555	563	592	579	558
8	578	583	583	592	596	585
10	647	635	630	650	657	643
Site mean						615

Table XV

E. saligna: wood density

Tree number	Density at sampling points, kg m^{-3} 10	30	50	70	90	Tree mean
1	608	568	568	565	565	581
2	553	579	573	589	572	570
3	593	621	594	574	545	597
4	541	567	565	552	545	555
5	493	494	489	440	472	484
6	606	643	627	646	601	624
7	561	542	533	529	519	542
8	510	502	476	477	455	492
9	524	506	492	495	464	506
10	522	493	486	492	458	501
Site mean						552

Table XVI

E. tereticornis: wood density

Tree number	Density at sampling points, kg m^{-3} 10	30	50	70	90	Tree mean
1	667	664	738	657	631	673
2	645	667	660	669	662	659
3	613	631	634	633	621	625
4	647	630	637	644	639	640
5	687	679	671	665	646	674
6	614	634	636	667	639	632
7	609	603	605	641	641	615
8	661	658	654	632	626	652
9	625	659	657	654	667	646
10	623	627	626	616	619	623
Site mean						643

Table XVII

E. camaldulensis: pulp evaluation

Cook number	Type*	Active alkali	Kappa number	Drainability, CSF	Beating, revs	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10} n$	Air resistance, s	ISO brightness, %	Opacity, %	Specific scattering coefficient, cm^2 g^{-1}	Moisture content, %
444	S	12.5	44.5	561	0	4.8	0.55	46.7	1.2	360	6.64	1.67	0.73	1.9	17.7	–	–	8.2
				384	1350	6.4	0.67	86.5	3.2	1810	8.21	4.84	2.13	12	15.8	–	–	8.3
				267	4050	7.8	0.75	107.9	3.8	2680	7.87	6.84	2.70	40	15.2	–	–	8.5
				180	6750	10.2	0.79	112.0	4.0	2970	7.43	7.29	2.86	96	14.2	–	–	8.4
443	S	15	33.3	530	0	5.2	0.56	49.6	1.3	400	6.61	1.93	0.79	2.8	19.3	–	–	8.2
				365	1350	6.9	0.69	90.4	3.2	1930	8.09	4.88	2.02	15	17.5	–	–	8.3
				273	4050	8.9	0.75	104.9	3.9	2680	7.56	6.18	2.50	40	16.2	–	–	8.2
				207	6750	10.4	0.79	109.3	4.1	2990	7.08	6.55	2.95	97	15.2	–	–	8.2
445	S	17.5	27.1	542	0	4.9	0.56	47.9	1.2	370	6.09	1.84	0.67	2.5	20.8	–	–	7.8
				382	1350	6.8	0.69	84.1	2.8	1570	7.54	4.36	1.78	14	19.1	–	–	7.9
				295	4050	8.4	0.76	96.1	3.3	2130	7.11	5.72	2.23	42	17.1	–	–	8.1
				213	6750	10.1	0.80	103.5	3.5	2450	7.03	5.87	2.70	110	15.8	–	–	8.1
445	B			425	0	5.2	0.52	35.4	1.3	310	6.13	1.29	0.39	2.5	85.3	87.2	638	7.3
				420	1350	6.4	0.65	67.3	2.9	1310	9.08	3.68	1.49	11	83.6	84.1	501	7.8
				327	4050	7.8	0.74	82.7	3.4	1920	8.71	4.96	2.15	27	82.1	80.4	405	7.8
				267	6750	9.2	0.78	89.2	3.8	2290	8.01	5.17	2.55	54	81.5	78.6	363	7.8
452	N	17.5	33.7	557	0	4.8	0.50	37.6	1.0	230	4.76	1.29	0.35	1.8	19.9	–	–	7.8
				390	1350	6.5	0.65	71.5	2.2	1030	7.05	3.69	1.44	10	18.3	–	–	7.8
				306	4050	7.8	0.71	83.4	2.7	1500	6.64	4.49	1.86	23	17.1	–	–	7.7
				239	6750	9.6	0.76	87.5	3.0	1780	6.53	5.08	2.17	55	15.6	–	–	7.9
451	NAQ	15	29.6	546	0	4.9	0.54	44.5	1.1	300	5.68	1.62	0.56	2.5	20.6	–	–	8.3
				376	1350	6.9	0.68	82.1	2.5	1370	8.14	4.27	1.67	14	18.9	–	–	8.0
				303	4050	7.7	0.74	94.0	3.2	2000	7.78	5.76	2.22	35	17.5	–	–	8.0
				203	6750	10.7	0.79	104.1	3.3	2320	7.42	5.76	2.74	87	16.5	–	–	8.1

Note: * S = Sulphate
B = Bleached
N = Soda
NAQ = Soda-anthraquinone

Table XVIII

E. citriodora: pulp evaluation

Cook number	Type*	Active alkali	Kappa number	Drainability, CSF	Beating, revs	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10}n$	Air resistance, s	ISO brightness, %	Opacity, %	Specific scattering coefficient, cm^2 g^{-1}	Moisture content, %
471	S	12.5	36.6	679	0	4.5	0.43	17.6	0.4	40	2.17	0.49	0	0.2	18.7	–	–	8.0
				527	1350	4.8	0.54	54.7	1.6	590	8.30	2.37	0.89	0.7	17.5	–	–	8.5
				360	4050	5.8	0.62	80.3	2.7	1430	10.38	4.16	1.63	4.4	16.7	–	–	8.1
				223	6750	8.1	0.67	94.1	3.5	2140	10.54	5.44	2.37	24	16.0	–	–	8.3
450	S	15	28.8	674	0	4.5	0.41	17.0	0.4	40	1.42	0.49	0	0.2	20.7	–	–	7.9
				552	1350	5.0	0.54	53.4	1.6	540	5.78	2.26	0.87	0.8	18.8	–	–	7.7
				406	4050	5.5	0.61	76.4	2.3	1150	8.73	3.86	1.60	3.0	18.1	–	–	7.7
				275	6750	7.5	0.65	88.9	3.0	1750	9.18	4.99	2.23	13	17.9	–	–	7.9
449	S	17.5	22.7	681	0	4.4	0.40	12.9	0.3	20	1.99	0.45	0	0.2	23.2	–	–	7.6
				576	1350	4.9	0.53	49.0	1.3	430	5.30	1.98	0.66	0.7	21.2	–	–	7.5
				456	4050	5.4	0.60	67.6	2.1	950	8.53	3.42	1.43	2.0	20.5	–	–	7.6
				315	6750	6.7	0.64	81.5	2.6	1390	9.55	4.53	1.93	8.7	20.1	–	–	7.6
				213	9450	9.1	0.68	90.5	3.2	1900	9.55	5.03	2.34	27	19.5	–	–	7.8
449	B			576	0	4.5	0.40	18.4	0.5	60	4.34	0.45	0	0.2	83.0	80.3	412	7.2
				593	1350	4.8	0.51	44.4	1.5	430	7.74	1.66	0.67	0.5	83.0	76.6	350	7.4
				485	4050	5.3	0.57	59.3	2.1	840	11.46	2.79	1.19	1.2	82.1	75.2	322	7.5
				393	6750	5.8	0.61	71.3	2.6	1210	11.90	3.66	1.55	3.2	81.9	74.8	317	7.7
				301	9450	6.7	0.64	77.0	2.8	1420	11.87	4.03	1.95	8.5	81.9	73.9	305	7.7
				228	12150	8.0	0.66	80.9	3.3	1760	11.83	4.57	1.98	18	81.4	74.3	294	7.5
456	N	17.5	26.5	666	0	4.5	0.40	13.7	0.3	20	0.66	0.46	0	0.2	23.6	–	–	7.2
				551	1350	4.8	0.52	44.3	1.2	330	4.71	1.70	0.53	0.7	20.5	–	–	7.4
				456	4050	5.1	0.58	61.4	1.7	700	7.34	2.75	1.07	1.7	21.1	–	–	7.4
				329	6750	6.0	0.62	70.9	2.3	1030	8.74	3.68	1.62	6.3	19.3	–	–	7.6
				221	9450	7.8	0.67	79.4	2.6	1360	8.94	4.46	1.95	23	19.0	–	–	7.4
455	NAQ	15	27.1	662	0	4.5	0.42	14.8	0.3	30	1.01	0.55	0	0.2	22.1	–	–	7.7
				525	1350	4.9	0.54	52.4	1.5	490	5.09	2.16	0.70	0.9	20.3	–	–	7.7
				423	4050	5.3	0.60	69.3	2.1	970	7.82	3.26	1.41	2.3	19.3	–	–	7.8
				307	6750	6.2	0.64	82.8	2.8	1500	8.94	4.41	1.92	8.6	19.1	–	–	7.7
				183	9450	9.1	0.69	92.1	3.1	1880	9.27	5.42	2.43	40	18.5	–	–	7.8

Note: * S = Sulphate
B = Bleached
N = Soda
NAQ = Soda-anthraquinone

Table XIX

E. cloeziana: pulp evaluation

Cook number	Type*	Active alkali	Kappa number	Drainability, CSF	Beating, revs	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10}n$	Air resistance, s	ISO brightness, %	Opacity, %	Specific scattering coefficient, cm^2 g^{-1}	Moisture content, %
514	S	12.5	52.5	705	0	4.4	0.43	21.8	0.6	80	3.70	0.56	0	0.3	14.5	–	–	8.4
				546	1350	4.7	0.58	55.1	1.9	680	8.31	2.45	1.05	1.0	13.2	–	–	8.9
				434	4050	4.8	0.66	75.5	2.9	1480	9.60	3.78	1.73	2.7	11.8	–	–	8.8
				317	6750	5.2	0.70	84.3	3.4	1910	9.94	4.82	2.29	7.5	11.3	–	–	8.7
				186	9450	6.0	0.73	95.9	3.6	2310	9.80	5.41	2.31	33	10.9	–	–	9.0
462	S	15	36.3	662	0	4.3	0.45	23.3	0.5	80	2.30	0.70	0	0.5	17.6	–	–	8.7
				499	1350	4.8	0.61	62.6	2.0	850	8.25	2.76	1.13	1.6	16.2	–	–	8.1
				365	4050	5.4	0.70	81.9	2.9	1580	9.07	4.56	1.84	7.1	15.9	–	–	8.3
				234	6750	6.9	0.75	95.6	3.6	2290	8.10	5.61	2.25	30	13.2	–	–	8.1
461	S	17.5	28.1	665	0	4.6	Sheets could not be peeled off discs .... all damaged											
				528	1350	4.9	0.59	58.5	1.8	700	7.17	2.56	1.03	1.4	18.5	–	–	7.6
				390	4050	5.3	0.67	79.5	2.7	1430	8.53	3.97	1.71	4.2	16.7	–	–	7.7
				268	6750	6.3	0.73	89.6	3.1	1900	8.74	5.03	2.16	19	15.4	–	–	7.9
461	B			575	0	4.6	0.40	17.3	0.6	70	3.40	0.51	0	0.3	84.9	83.0	493	7.4
				567	1350	4.8	0.55	46.5	1.8	550	7.18	1.84	0.73	1.0	83.5	78.9	392	7.6
				468	4050	5.1	0.65	61.3	2.6	1070	7.78	3.03	1.39	2.9	82.3	75.3	320	7.8
				385	6750	5.5	0.68	71.2	2.8	1350	10.18	3.62	1.60	5.3	81.6	74.0	296	7.7
				315	9450	5.9	0.71	75.3	3.6	1830	8.36	4.22	2.00	12	80.8	72.5	277	7.8
				242	12150	6.4	0.73	83.4	3.9	2200	9.31	4.71	2.31	28	80.3	71.6	255	8.0
476	N	17.5	44.8	712	0	4.4	Sheets could not be peeled off discs											
				576	1350	4.6	0.53	43.3	1.2	330	5.58	1.53	0.49	0.7	17.2	–	–	7.6
				474	4050	4.8	0.62	63.0	2.0	830	7.67	2.90	1.17	1.6	15.7	–	–	7.6
				369	6750	5.0	0.66	69.6	2.4	1120	8.31	3.50	1.53	3.7	15.1	–	–	7.4
				238	9450	5.8	0.69	78.3	2.9	1530	8.44	4.29	1.84	13	14.5	–	–	7.7
478	NAQ	15	36.9	666	0	4.5	0.41	18.3	0.5	50	2.32	0.53	0	0.3	18.8	–	–	7.5
				538	1350	4.8	0.56	53.4	1.6	560	6.68	2.13	0.88	1.0	16.8	–	–	7.5
				398	4050	5.0	0.64	73.7	2.2	1080	8.88	3.56	1.52	3.1	15.4	–	–	7.6
				278	6750	5.9	0.70	85.0	2.8	1590	9.13	4.77	2.05	13	14.4	–	–	7.8

Note: * S = Sulphate
B = Bleached
N = Soda
NAQ = Soda-anthraquinone

Table XX

E. grandis: pulp evaluation

Cook number	Type*	Active alkali	Kappa number	Drainability, CSF	Beating, revs	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10}n$	Air resistance, s	ISO brightness, %	Opacity, %	Specific scattering coefficient, cm^2 g^{-1}	Moisture content, %
446	S	12.5	60.9	601	0	4.6	0.53	47.5	1.1	310	6.80	1.68	0.60	1.9	14.6	–	–	8.5
				408	1350	6.0	0.69	93.5	2.9	1790	8.71	5.11	2.23	16	12.6	–	–	8.6
				275	4050	8.4	0.78	117.2	3.7	2780	7.65	7.11	2.59	69	11.5	–	–	8.2
				197	6750	10.4	0.82	122.1	4.1	3210	7.21	7.40	3.03	239	10.4	–	–	8.7
447	S	15	37.9	575	0	4.8	0.55	51.2	1.1	330	6.43	1.76	0.77	2.8	18.7	–	–	8.3
				406	1350	6.3	0.71	94.1	2.9	1780	8.84	5.03	2.23	19	15.7	–	–	8.6
				312	4050	8.0	0.78	113.5	3.5	2590	8.32	6.90	2.67	67	14.1	–	–	8.4
				219	6750	10.2	0.82	120.1	3.9	3000	7.99	7.50	2.99	188	12.8	–	–	8.7
448	S	17.5	28.9	564	0	4.8	0.55	49.7	1.0	320	6.59	1.73	0.66	3.1	20.1	–	–	8.1
				438	1350	6.2	0.70	90.0	2.7	1620	9.15	4.61	1.93	19	17.8	–	–	8.1
				313	4050	7.8	0.78	107.8	3.3	2320	8.39	6.04	2.39	58	16.0	–	–	8.2
				236	6750	10.1	0.82	114.9	3.8	2820	8.00	6.68	2.72	145	14.1	–	–	8.3
448	B			431	0	5.1	0.52	35.6	1.2	260	6.40	1.30	0.40	3.5	83.5	87.3	596	7.4
				443	1350	6.1	0.68	72.2	2.6	1250	9.89	3.40	1.55	15	82.6	81.9	445	7.7
				362	4050	7.2	0.76	89.5	3.5	2050	10.32	4.87	2.26	39	81.3	78.3	364	7.8
				292	6750	8.6	0.79	100.1	3.7	2440	9.64	5.74	2.49	82	79.8	76.7	325	7.8
453	N	17.5	39.5	586	0	4.8	0.52	41.0	0.9	220	5.60	1.38	0.56	2.7	19.8	–	–	8.1
				436	1350	5.7	0.66	76.2	2.2	1080	8.12	3.58	1.67	13	17.7	–	–	8.0
				358	4050	6.4	0.74	93.0	2.8	1720	8.04	5.00	2.20	32	16.1	–	–	7.9
				288	6750	7.3	0.77	99.2	3.3	2160	7.71	5.70	2.52	66	14.8	–	–	8.2
454	NAQ	15	34.6	565	0	4.9	0.55	51.1	1.0	320	6.72	1.73	0.68	3.4	18.2	–	–	8.2
				412	1350	6.1	0.70	90.0	2.6	1510	8.90	4.50	1.91	21	16.0	–	–	8.3
				321	4050	7.2	0.78	107.0	3.2	2240	8.24	6.20	2.51	63	14.4	–	–	8.3
				217	6750	9.9	0.82	115.5	3.7	2790	7.92	6.90	2.66	179	13.0	–	–	8.4

Note: * S = Sulphate
B = Bleached
N = Soda
NAQ = Soda-anthraquinone

Table XXI

E. maculata: pulp evaluation

Cook number	Type*	Active alkali	Kappa number	Drainability, CSF	Beating, revs	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10}n$	Air resistance, s	ISO brightness, %	Opacity, %	Specific scattering coefficient, cm^2 g^{-1}	Moisture content, %
297	S	12.5	37.8	644	0	4.5	0.49	20.8	0.5	50	1.96	0.58	0	0.4	22.0	–	–	8.0
				462	1350	5.5	0.65	74.8	2.1	990	7.28	3.75	1.61	2.8	18.7	–	–	8.0
				307	4050	7.3	0.73	101.0	3.2	2080	7.97	5.72	2.47	22	17.2	–	–	8.2
				180	6750	11.1	0.78	114.9	3.8	2860	7.53	6.84	2.92	113	16.1	–	–	8.2
296	S	15	26.6	619	0	4.6	0.50	20.6	0.4	50	1.68	0.68	0	0.5	24.5	–	–	7.4
				470	1350	5.5	0.65	74.3	2.2	1050	7.22	3.45	1.42	3.1	21.8	–	–	7.7
				346	4050	6.5	0.72	97.8	2.9	1880	8.44	5.26	2.25	16	20.1	–	–	7.7
				238	6750	8.6	0.76	110.9	3.5	2480	8.28	6.50	2.72	43	19.2	–	–	7.8
295	S	17.5	22.3	631	0	4.7	0.47	21.5	0.4	60	1.74	0.58	0	0.5	26.7	–	–	7.6
				489	1350	5.6	0.63	70.0	1.9	850	9.27	3.11	1.11	2.5	24.4	–	–	7.3
				377	4050	6.4	0.72	89.6	2.8	1680	9.23	4.83	1.92	11	22.5	–	–	7.3
				300	6750	7.5	0.74	101.1	3.3	2190	9.15	5.62	2.11	25	21.8	–	–	7.3
295	B			518	0	4.7	0.46	21.7	0.6	80	4.48	0.57	0	0.5	86.3	81.9	494	7.4
				523	1350	4.9	0.59	49.1	1.9	630	7.78	2.13	0.79	1.7	84.1	79.8	404	7.5
				443	4050	5.6	0.66	67.3	2.6	1190	10.48	3.42	1.50	4.8	82.7	77.1	347	7.6
				351	6750	6.3	0.71	81.5	3.4	1810	11.24	4.40	1.83	12	82.2	75.4	318	7.5
				288	9450	7.4	0.74	89.7	3.5	2070	10.90	4.95	2.06	29	82.1	73.7	294	7.7
276	N	17.5	27.6	633	0	4.6	0.48	15.8	0.4	30	1.70	0.49	0	0.4	26.7	–	–	7.3
				498	1350	5.2	0.60	57.2	1.6	580	6.26	2.51	0.90	2.0	24.2	–	–	7.4
				380	4050	5.7	0.68	78.6	2.4	1230	7.91	4.01	1.66	7.2	22.5	–	–	7.5
				289	6750	6.5	0.72	91.2	3.0	1780	8.03	4.86	2.17	17	21.5	–	–	7.5
298	NAQ	15	24.0	636	0	4.5	0.48	18.5	0.4	40	1.22	0.54	0	0.5	26.2	–	–	7.6
				478	1350	5.4	0.62	66.8	1.9	820	8.32	2.96	1.02	2.1	23.8	–	–	7.3
				341	4050	6.2	0.69	88.3	2.7	1520	8.91	4.50	1.70	8.5	22.3	–	–	7.4
				260	6750	7.5	0.72	98.0	3.0	1950	8.87	5.45	2.19	22	21.5	–	–	7.3

Note: * S = Sulphate
B = Bleached
N = Soda
NAQ = Soda-anthraquinone

Table XXIA

E. maculata: pulp evaluation, soda and soda—anthraguinone cooks

Cook number	Type*	Active alkali	Kappa number	Drainability, CSF	Beating, revs	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $log_{10}n$	Air resistance, s	ISO brightness, %	Opacity, %	Specific scattering coefficient, cm^2 g^{-1}	Moisture content, %
299	N	15	37.7	692	0	4.5	Sheets did not separate from drying discs											
				534	1350	4.8	0.57	53.7	1.4	466	5.06	2.06	0.79	1.0	22.6	–	–	7.6
				414	4050	5.2	0.66	75.4	2.2	1083	7.60	3.81	1.54	3.5	21.1	–	–	7.9
				324	6750	5.7	0.70	88.7	2.8	1631	7.86	4.78	2.05	9.1	20.8	–	–	7.7
				190	9450	7.8	0.75	106.0	3.2	2196	8.94	5.90	2.29	49	19.4	–	–	7.7
276	N	17.5	27.6	633	0	4.6	0.48	15.8	0.4	30	1.70	0.49	0	0.4	26.7	–	–	7.3
				498	1350	5.2	0.60	57.2	1.6	583	6.26	2.51	0.90	2.0	24.2	–	–	7.4
				380	4050	5.7	0.68	78.6	2.4	1229	7.91	4.01	1.66	7.2	22.5	–	–	7.5
				289	6750	6.5	0.70	91.2	3.0	1784	8.03	4.86	2.17	17	21.5	–	–	7.5
301	NAQ	12.5	34.5	665	0	4.5	0.48	18.1	0.4	43	1.55	0.53	0	0.3	21.7	–	–	8.0
				497	1350	5.0	0.60	66.1	1.7	703	7.87	2.84	1.11	1.5	20.0	–	–	7.8
				353	4050	5.8	0.70	95.1	2.6	1578	8.77	4.83	1.91	8.4	18.8	–	–	7.5
				242	6750	7.2	0.73	106.6	3.1	2097	9.27	5.92	2.28	25	18.2	–	–	7.9
300	NAQ	15	30.6	636	0	4.6	0.48	20.0	0.5	52	1.99	0.55	0	0.4	25.3	–	–	7.8
		1+1		474	1350	5.1	0.60	64.7	1.7	694	9.10	2.84	1.00	1.8	23.6	–	–	7.6
				366	4050	5.6	0.67	86.9	2.5	1407	8.98	4.36	1.76	5.9	22.5	–	–	7.4
				262	6750	6.7	0.72	100.8	3.0	1941	9.94	5.39	2.07	19	21.3	–	–	7.7
298	NAQ	15	24.0	636	0	4.5	0.48	18.5	0.4	43	1.22	0.54	0	0.5	26.2	–	–	7.6
		1+2		479	1350	5.4	0.62	66.8	1.9	817	8.32	2.96	1.02	2.1	23.8	–	–	7.3
				341	4050	6.2	0.69	88.3	2.7	1524	8.91	4.50	1.70	8.5	22.3	–	–	7.4
				260	6750	7.5	0.72	98.0	3.0	1945	8.87	5.45	2.19	22	21.5	–	–	7.3

Note: * S = Sulphate
B = Bleached
N = Soda
NAQ = Soda-anthraquinone

Table XXII

E. maidenii: pulp evaluation

Cook number	Type*	Active alkali	Kappa number	Drainability, CSF	Beating, revs	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10}n$	Air resistance, s	ISO brightness, %	Opacity, %	Specific scattering coefficient, cm^2 g^{-1}	Moisture content, %
482	S	12.5	43.0	628	0	4.5	0.49	37.1	0.8	170	5.45	1.25	0.26	0.6	18.3	–	–	7.9
				480	1350	5.2	0.64	82.0	2.7	1400	9.65	4.19	1.66	2.6	16.8	–	–	8.4
				349	4050	6.1	0.72	108.8	3.4	2350	9.05	6.42	2.48	10	14.8	–	–	8.0
				240	6750	8.2	0.77	120.1	3.9	3030	8.30	7.24	2.59	42	13.6	–	–	8.0
459	S	15	31.2	620	0	4.6	0.51	41.1	0.8	200	4.63	1.30	0.29	0.8	22.0	–	–	8.1
				504	1350	5.0	0.64	81.9	2.6	1370	8.58	4.27	1.63	2.9	19.6	–	–	8.0
				380	4050	6.3	0.72	105.0	3.4	2290	8.50	6.18	2.43	11	17.3	–	–	8.1
				246	6750	9.1	0.78	119.6	4.0	3080	8.36	7.35	2.89	45	15.7	–	–	8.0
460	S	17.5	24.1	645	0	4.8	0.50	37.9	0.7	170	3.85	1.24	0.10	0.6	22.8	–	–	7.5
				493	1350	5.5	0.64	79.1	2.5	1270	8.77	4.21	1.41	3.2	21.4	–	–	7.7
				394	4050	6.4	0.72	99.8	3.3	2150	8.82	5.66	2.16	9.6	19.2	–	–	8.4
				261	6750	9.0	0.78	108.4	3.6	2540	8.16	6.52	2.61	39	17.5	–	–	7.8
460	B			519	0	4.9	0.46	29.4	1.0	200	5.82	1.00	0.18	0.7	85.7	85.4	569	7.2
				490	1350	5.5	0.61	66.0	2.5	1100	9.63	3.30	1.33	2.6	84.9	80.6	440	7.5
				397	4050	6.2	0.69	85.6	3.2	1740	9.48	4.73	1.95	8.0	83.8	77.3	364	7.8
				308	6750	7.5	0.74	92.8	3.6	2150	9.28	5.35	2.35	21	83.1	75.5	332	7.6
				249	9450	8.7	0.76	96.5	3.8	2360	9.18	5.77	2.44	40	82.0	75.0	309	7.7
477	N	17.5	32.2	669	0	4.7	0.46	34.9	0.8	160	4.02	1.11	0.06	0.7	23.0	–	–	7.5
				500	1350	5.1	0.60	72.5	2.1	970	8.78	3.32	1.30	2.5	20.8	–	–	7.4
				385	4050	5.8	0.67	93.5	2.8	1710	8.53	4.93	1.84	6.2	19.3	–	–	7.5
				323	6750	6.5	0.72	100.2	3.2	2080	8.16	5.57	2.06	14	18.1	–	–	7.5
				235	9450	8.2	0.76	103.3	3.5	2370	8.27	6.19	2.54	34	16.9	–	–	7.5
480	NAQ	15	30.6	611	0	4.6	0.49	39.7	0.8	190	4.85	1.27	0.21	0.7	22.8	–	–	7.6
				491	1350	5.3	0.61	81.4	2.3	1190	9.04	3.77	1.42	2.0	20.6	–	–	8.1
				371	4050	6.1	0.70	101.4	2.9	1880	8.96	5.66	2.01	7.2	18.8	–	–	8.2
				269	6750	8.0	0.75	113.4	3.5	2530	8.78	6.73	2.50	25	17.3	–	–	8.2

Note: * S = Sulphate
B = Bleached
N = Soda
NAQ = Soda-anthraquinone

Table XXIII

E. saligna: pulp evaluation

Cook number	Type*	Active alkali	Kappa number	Drainability, CSF	Beating, revs	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10}n$	Air resistance, s	ISO brightness, %	Opacity, %	Specific scattering coefficient, cm^2 g^{-1}	Moisture content, %
513	S	12.5	42.6	651	0	4.6	0.49	35.2	0.8	170	6.25	1.11	0.40	0.7	15.3	–	–	8.6
				494	1350	5.1	0.62	76.7	2.5	1240	11.66	3.74	1.66	2.9	13.4	–	–	8.6
				387	4050	5.6	0.68	97.1	3.4	2140	11.49	5.37	2.29	10	12.4	–	–	8.7
				261	6750	7.1	0.75	113.8	3.9	2870	10.69	6.70	3.02	41	11.4	–	–	8.6
511	S	15	30.1	627	0	4.6	0.48	36.1	0.8	170	5.72	1.12	0.21	0.8	18.3	–	–	8.1
				488	1350	5.2	0.62	73.7	2.4	1130	11.50	3.76	1.58	3.7	16.1	–	–	8.3
				377	4050	5.9	0.70	99.2	3.3	2150	11.63	5.56	2.37	13	14.5	–	–	8.0
				295	6750	6.9	0.72	109.2	3.7	2580	11.58	6.32	2.56	28	14.0	–	–	7.9
512	S	17.5	24.3	614	0	4.7	0.46	33.4	0.8	160	5.64	1.04	0.24	0.8	18.8	–	–	8.0
				504	1350	5.2	0.61	70.3	2.3	1060	11.10	3.30	1.36	3.8	16.3	–	–	8.2
				414	4050	6.1	0.69	87.4	3.0	1750	11.16	4.71	1.92	12	15.3	–	–	8.5
				323	6750	6.9	0.72	98.6	3.4	2180	10.77	5.65	2.46	26	14.1	–	–	8.2
				252	9450	8.0	0.75	103.5	3.6	2430	10.52	5.99	2.70	48	13.5	–	–	8.2
512	B			541	0	4.6	0.46	29.1	0.9	180	4.24	1.01	0.15	0.9	83.9	85.0	539	7.6
				504	1350	5.3	0.60	59.8	2.2	900	10.54	3.08	1.23	3.1	82.2	81.5	435	7.5
				428	4050	5.9	0.67	77.3	3.0	1520	10.30	4.25	1.80	8.1	81.0	78.6	370	7.5
				335	6750	7.0	0.73	88.7	3.4	1980	10.05	5.09	2.25	22	79.9	76.0	321	7.5
				260	9450	8.6	0.75	92.3	3.5	2147	10.03	5.46	2.56	36	78.6	75.2	300	7.5
515	N	17.5	35.1	662	0	4.6	0.46	22.2	0.5	70	4.03	0.58	0	0.5	19.1	–	–	8.3
				526	1350	4.9	0.57	57.6	1.9	710	10.35	2.53	1.04	2.4	17.0	–	–	8.4
				453	4050	5.3	0.64	72.7	2.5	1190	10.65	3.68	1.47	5.6	16.0	–	–	8.7
				384	6750	5.6	0.66	77.7	2.6	1340	11.35	4.23	1.85	9.0	15.2	–	–	8.3
				307	9450	6.1	0.71	91.2	3.3	1970	10.59	4.68	2.00	20	14.3	–	–	8.5
				258	12,150	6.9	0.73	93.3	3.3	2020	10.94	5.26	2.24	37	13.9	–	–	8.5
516	NAQ	15	29.0	614	0	4.7	0.44	29.1	0.7	110	5.11	0.86	0.30	0.7	18.9	–	–	8.3
				492	1350	5.3	0.58	66.4	2.1	890	11.04	3.06	1.35	3.5	16.5	–	–	8.4
				406	4050	5.7	0.67	83.3	2.9	1590	11.25	4.45	1.89	9.9	14.9	–	–	8.5
				302	6750	7.0	0.70	95.4	3.1	1920	11.40	5.20	2.13	23	14.2	–	–	8.3
				262	9450	7.4	0.74	98.7	3.5	2260	11.15	5.77	2.38	42	13.8	–	–	8.5

Note: * S = Sulphate
B = Bleached
N = Soda
NAQ = Soda-anthraquinone

Table XXIV

E. tereticornis: pulp evaluation

Cook number	Type*	Active alkali	Kappa number	Drainability, CSF	Beating, revs	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10}n$	Air resistance, s	ISO brightness, %	Opacity, %	Specific scattering coefficient, cm^2 g^{-1}	Moisture content, %
519	S	12.5	41.1	664	0	4.7	0.43	26.9	0.6	100	4.57	0.82	0	0.3	17.1	–	–	7.9
				511	1350	5.1	0.52	64.2	2.0	840	10.34	2.84	1.06	0.9	15.7	–	–	7.9
				388	4050	5.7	0.60	89.1	3.0	1750	11.73	4.84	1.95	3.2	14.7	–	–	8.6
				248	6750	7.0	0.64	103.7	3.5	2350	12.05	5.90	2.37	10	14.3	–	–	8.5
520	S	15	29.6	630	0	4.7	0.42	26.4	0.6	80	4.90	0.78	0	0.4	19.6	–	–	8.1
				493	1350	5.2	0.53	61.7	1.8	720	10.24	2.75	1.01	1.0	17.9	–	–	8.2
				424	4050	5.7	0.59	79.1	2.8	1440	12.85	4.15	1.60	2.5	16.6	–	–	8.1
				324	6750	6.4	0.62	89.2	3.0	1760	12.91	4.89	2.00	5.8	16.2	–	–	8.3
				251	9450	7.1	0.65	99.2	3.5	2230	12.50	5.61	2.12	11	15.7	–	–	8.3
521	S	17.5	23.6	644	0	4.6	0.43	22.5	0.5	70	3.19	0.74	0.13	0.4	21.8	–	–	8.0
				522	1350	5.0	0.53	56.4	1.8	680	9.66	2.48	0.94	1.0	20.1	–	–	8.1
				438	4050	5.4	0.60	76.0	2.6	1280	11.67	3.68	1.44	2.5	19.2	–	–	8.4
				341	6750	6.3	0.64	84.8	2.9	1600	12.32	4.59	1.83	6.0	18.2	–	–	8.2
				286	9450	6.9	0.66	90.4	3.1	1872	12.25	5.09	2.06	10	17.8	–	–	8.2
521	B			529	0	4.6	0.42	23.3	0.7	110	3.16	0.74	0	0.4	85.1	84.3	529	7.2
				525	1350	5.3	0.52	50.6	1.7	560	7.71	2.13	0.78	1.0	84.2	81.5	451	7.5
				452	4050	5.7	0.59	65.7	2.5	1076	11.15	3.08	1.31	2.1	83.3	79.8	405	7.4
				360	6750	6.5	0.64	77.0	2.9	1484	11.49	4.12	1.84	5.0	82.8	78.5	371	7.6
				318	9450	7.0	0.65	80.6	3.0	1640	11.15	4.27	1.92	7.2	82.3	78.4	365	7.5
				264	12,150	8.1	0.67	82.6	3.2	1750	11.46	4.79	2.03	14.1	81.8	78.0	355	7.6
522	N	17.5	33.4	636	0	4.6	Sheets could not be separated from drying discs											
				536	1350	4.8	0.49	46.5	1.3	380	7.51	1.77	0.60	0.7	18.2	–	–	8.1
				462	4050	5.3	0.55	60.9	2.0	790	10.20	2.68	1.01	1.4	17.1	–	–	8.3
				377	6750	5.8	0.59	71.6	2.4	1140	11.89	3.42	1.40	3.0	16.6	–	–	8.1
				315	9450	6.2	0.62	78.1	2.8	1440	10.65	3.90	1.53	6.2	16.2	–	–	7.7
				240	12,150	7.1	0.64	79.3	2.9	1530	10.45	4.21	1.73	12	15.9	–	–	8.3
523	NAQ	15	31.8	630	0	4.7	Sheets could not be separated from drying discs											
				515	1350	5.0	0.51	53.4	1.5	520	9.39	2.18	0.83	0.8	19.7	–	–	8.1
				434	4050	5.3	0.57	70.8	2.3	1080	10.66	3.43	1.28	1.7	18.1	–	–	8.2
				360	6750	5.7	0.60	80.9	2.6	1350	11.37	4.26	1.71	3.8	17.9	–	–	8.3
				257	9450	6.9	0.64	87.5	3.0	1720	11.85	4.81	2.04	10	17.6	–	–	8.6

Note: * S = Sulphate
B = Bleached
N = Soda
NAQ = Soda-anthraquinone

Table XXV

Neutral sulphite semi-chemical cooks: pulp evaluation valley beater

Species	Cook number	Drainability, CSF	Beating, time, min	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10}n$	Air resistance, s	ISO brightness, %	Moisture content, %
Eucalyptus camaldulensis	537	560	0*	4.9	0.46	40.1	1.3	337	6.09	1.64	0.71	1.0	21.5	9.2
		542	0†	4.7	0.47	42.5	1.4	388	6.39	1.70	0.69	1.7	21.2	9.3
		511	7	4.8	0.51	51.7	1.6	540	6.21	2.14	0.99	2.9	20.9	9.5
		460	14	5.1	0.53	56.1	1.9	673	6.17	2.58	1.12	3.7	20.7	9.3
		387	21	5.6	0.56	63.6	2.1	884	6.47	3.01	1.34	7.7	20.5	9.3
		316	28	5.9	0.60	71.5	2.3	1071	6.05	3.50	1.54	21	19.8	9.4
		256	35	7.1	0.62	73.6	2.5	1190	5.78	3.94	1.85	37	19.4	9.3
E. citriodora	542	640	0*	4.6	0.42	24.0	0.7	116	3.34	0.75	0	0.3	18.0	8.1
		607	0†	4.8	0.43	25.5	0.8	139	3.81	0.82	0.06	0.4	18.0	8.2
		552	7	4.7	0.47	36.3	1.1	272	5.01	1.30	0.41	0.8	18.1	8.4
		481	14	5.0	0.49	41.7	1.3	368	5.95	1.59	0.64	1.4	17.9	8.4
		390	21	5.4	0.53	52.7	1.6	573	6.85	2.22	0.97	4.1	17.7	8.5
		311	28	6.2	0.55	57.7	1.9	745	7.20	2.51	1.26	8.4	17.4	8.5
		218	35	8.6	0.60	66.4	2.3	1029	7.12	3.15	1.60	32	16.9	8.5
E. cloeziana	543	679	0*	4.4	0.37	18.7	0.6	79	2.66	0.56	0	0.2	16.7	9.0
		643	0†	4.5	0.39	23.7	0.7	115	3.01	0.69	0	0.2	16.8	9.0
		590	7	4.5	0.43	32.0	1.0	205	3.65	0.98	0.09	0.3	16.9	9.1
		544	14	4.6	0.45	38.1	1.2	284	4.26	1.29	0.46	0.5	16.7	9.3
		468	21	4.8	0.49	44.1	1.4	397	4.62	1.68	0.69	0.8	16.6	9.1
		394	28	4.8	0.51	50.9	1.6	524	5.20	2.01	0.87	1.6	16.5	9.2
		333	35	5.0	0.54	56.4	1.8	675	5.23	2.36	1.19	3.7	16.5	9.3
		263	42	5.3	0.56	57.8	2.0	761	5.36	2.48	1.30	6.7	16.2	9.2
E. grandis	541	550	0*	4.7	0.48	46.7	1.3	391	6.21	1.76	0.72	2.1	19.2	9.5
		506	0†	4.7	0.47	46.1	1.4	402	5.94	1.73	0.86	2.2	19.4	9.3
		476	7	5.2	0.52	55.5	1.5	517	6.39	2.18	1.07	4.4	19.1	9.3
		401	14	5.4	0.54	63.2	1.7	700	6.95	2.85	1.29	8.0	19.0	9.2
		345	21	5.8	0.61	76.7	2.1	1038	6.66	3.49	1.68	25	18.2	9.3
		275	28	7.2	0.65	82.5	2.3	1196	6.16	4.04	1.97	60	17.5	9.4
		219	35	8.6	0.67	89.0	2.5	1442	5.77	4.32	2.10	124	17.6	9.4

E. maculata	540	561	0*	5.6	0.47	33.2	1.0	203	4.78	1.16	0.27	0.6	24.4	8.7
		543	0†	4.8	0.49	36.0	1.1	250	4.80	1.25	0.39	1.2	24.3	8.6
		497	7	4.9	0.53	45.5	1.3	390	5.70	1.85	0.73	2.5	23.9	8.5
		418	14	5.4	0.58	57.5	1.6	606	6.53	2.35	1.05	6.1	23.4	8.7
		349	21	6.1	0.61	67.6	1.9	824	6.76	3.01	1.33	16	22.9	8.5
		275	28	7.6	0.65	75.2	2.2	1050	6.87	3.55	1.72	34	21.9	8.7
		208	35	10.7	0.70	82.9	2.5	1372	6.48	4.06	1.99	114	20.8	8.8
E. maidenii	544	528	0*	4.9	0.47	41.4	1.6	425	5.90	1.61	0.82	1.2	19.1	8.5
		474	0†	5.4	0.48	44.9	1.7	483	6.27	1.86	0.84	1.8	18.9	8.6
		404	7	5.9	0.54	57.7	2.0	704	6.05	2.61	1.23	4.8	18.9	9.3
		354	14	6.5	0.57	66.9	2.2	954	6.62	3.08	1.36	10	18.3	8.4
		275	21	8.1	0.62	73.0	2.4	1101	6.67	3.71	1.55	22	17.7	8.6
		212	28	10.6	0.66	80.1	2.6	1322	5.92	4.15	1.96	55	16.9	8.7
		143	35	16.3	0.68	83.1	2.8	1491	5.95	4.32	2.02	105	15.9	9.4
E. saligna	545	671	0*	4.6	0.42	27.4	0.8	147	4.62	0.98	0.09	0.3	17.6	9.9
		588	0†	4.6	0.43	33.0	1.1	228	5.62	1.18	0.42	0.6	17.7	9.8
		542	7	4.8	0.46	43.2	1.3	364	6.37	1.68	0.65	0.8	17.7	9.4
		482	14	5.0	0.50	50.7	1.5	483	6.78	2.24	0.87	1.4	17.4	9.7
		426	21	5.0	0.52	57.0	1.8	656	6.80	2.56	1.12	2.7	17.4	9.6
		352	28	5.5	0.55	63.9	2.0	831	6.60	3.05	1.37	6.3	17.0	8.9
		286	35	6.2	0.59	70.4	2.3	1020	6.34	3.58	1.55	16	16.8	9.2
		217	42	7.5	0.62	75.2	2.5	1181	6.30	3.75	1.87	40	16.5	10.0
E tereticornis	547	653	0*	4.7	0.40	24.2	0.8	131	3.88	0.87	0.06	0.2	18.2	8.9
		630	0†	4.6	0.40	26.6	0.9	152	4.43	0.91	0.03	0.3	18.5	9.0
		600	7	4.6	0.41	30.8	1.0	199	4.51	1.14	0.06	0.3	18.4	8.8
		545	14	4.9	0.44	38.6	1.3	319	5.15	1.51	0.34	0.5	18.5	8.9
		502	21	4.8	0.46	45.5	1.4	421	5.36	1.83	0.60	0.7	18.3	8.8
		442	28	5.0	0.48	49.6	1.6	515	4.93	1.97	0.81	1.1	18.4	9.4
		388	35	5.3	0.51	54.2	1.9	674	5.46	2.37	1.03	1.8	18.5	9.2
		320	42	5.7	0.54	61.8	2.1	861	5.24	2.75	1.23	4.4	18.4	9.3

Notes: * Unbeaten pulp straight from refiner
† Unbeaten pulp dispersed in valley beater

Table XXVI

E. grandis: chemi-thermal mechanical pulp – pulp evaluation valley beater

Cook number	Drainability, CSF	Beating, time, min	Drainage time, s	Apparent density, g cm^{-3}	Tensile index, N m g^{-1}	Stretch, %	Tensile energy absorption index, mJ g^{-1}	Tear index, mN m^2 g^{-1}	Burst index, kPa m^2 g^{-1}	Folding endurance, $\log_{10}n$	Air resistance, s	ISO brightness, %	Moisture content, %
573	629	0	4.6	0.37	21.2	1.1	154	3.88	0.85	0.03	0.3	10.2	8.3
	558	7	4.6	0.41	28.7	1.3	237	3.99	1.09	0.06	0.5	10.2	8.6
	482	14	4.7	0.43	33.4	1.3	282	4.05	1.43	0.22	0.8	10.2	8.7
	392	21	5.0	0.46	42.6	1.7	478	4.35	1.85	0.66	2.2	10.2	8.6
	281	28	5.5	0.51	50.5	2.0	649	4.41	2.35	0.92	8.0	10.1	8.7
	194	35	6.7	0.52	53.6	2.2	783	4.26	2.59	0.99	20	10.6	9.0