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L68

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SUMMARY

Pulping characteristics of *Eucalyptus saligna/grandis* growing in Uganda

Three samples of *Eucalyptus saligna/grandis* grown in Uganda were examined to determine wood density, chemical composition, fibre dimensions, and pulping characteristics by the sulphate process.

The samples were of 9-year-old trees and 17-year-old trees from the Kajansi Forest Reserve, and 11-year-old trees from Nagojje Forest Reserve. The differences in wood density, chemical composition,and fibre dimensions were small and unlikely to be significant in commerical production, but there were indications that both age of sample and growing conditions affect wood density, fibre dimensions and the strength characteristics of pulp.

All three samples when pulped by the sulphate process yielded more than 50% of a bleachable pulp with good strength characteristics. Pulp from the 9-year-old sample from Kajansi had the highest bonding strength; that from the 17-year-old sample from Kajansi the highest tearing strength; that from the 11-year-old sample from Nagojje was weakest in all respects.

The pulps could be bleached by a four-stage process of successive applications of chlorine, sodium hydroxide, sodium hypochlorite and chlorine dioxide to yield pulps with satisfactory brightness (86, MgO=100) and with strength properties only a little lower than those of unbleached pulps.

RÉSUMÉ

Caractéristiques de la production de pâte *d'Eucalyptus saligna/grandis* de l'Ouganda

Trois échantillons d'*Eucalyptus saligna/grandis* provenant de l'Ouganda ont été examinés pour déterminer la densité, la composition chimique, les dimensions des fibres du bois ainsi que les caractéristiques de la production de pâte par le procédé au sulfate.

Les échantillons provenaient d'arbres de 9 ans et de 17 ans de la Réserve forestière de Kajansi et d'arbres de 11 ans de la Réserve forestière de Nagojje. Les différences en ce qui concerne la densité, la composition chimique et les dimensions des fibres du bois étaient faibles et il est peu probable qu'elles puissent présenter de l'importance dans la production commerciale, mais il y avait des indications selon lesquelles l'âge de l'échantillon et les conditions de croissance sont des facteurs influençant la densité, les dimensions des fibres du bois ainsi que les caractéristiques de résistance de la pâte.

Les trois échantillons, réduits en pâte par le procédé au sulfate, ont fourni plus de 50% de pâte pouvant être blanchie avec de bonnes caractéristiques de résistance. La pâte provenant de l'échantillon de 9 ans de Kajansi présentait la résistance à l'arrachage la plus élevée; celle provenant de l'échantillon de 17 ans de Kajansi présentait la résistance au déchirement la plus élevée; celle provenant de l'échantillon de 11 ans de Nagojje était la plus faible sous tous les rapports.

Les pâtes ont pu être blanchies par un processus à quatre phases, avec applications successives de chlore, d'hydroxyde de sodium, d'hypochlorite de sodium et de dioxyde de chlore pour obtenir des pâtes avec une blancheur satisfaisante (86, MgO = 100) et avec des propriétés de résistance seulement légèrement inférieures à celles des pâtes non blanchies.

RESUMEN

Características de pulpación del *Eucalyptus saligna/grandis* procedente de Uganda

Fueron analizadas tres muestras de *Eucalyptus saligna/grandis* cultivado en Uganda con el fin de determinar la densidad de la madera, composición química, dimensiones de las fibras y sus características de pulpación mediante el proceso de sulfato.

Las muestras fueron tomadas de árboles de 9 años y árboles de 17 años cultivados en la Reserva Forestal de Kajansi, así como de árboles de 11 años procedentes de la Reserva Forestal de Nagojje. Las diferencias entre la densidad de la madera, la composición química y las dimensiones de las fibras fueron pequeñas y poco probables de ofrecer interés en la producción comercial, pero se observó que tanto la edad de la muestra como las condiciones del cultivo afectan la densidad de la madera, las dimensiones de las fibras y las características de resistencia de la pulpa.

Las tres muestras, cuando fueron pulpadas mediante el método de sulfato, produjeron más de un 50% de pasta blanqueable con buenas características de resistencia. La pulpa procedente de la muestra de 9 años de Kajansi registró la más alta resistencia de ligazón; la procedente de la muestra de 17 años de Kajansi la más alta resistencia al rasgado; siendo la procedente de la muestra de 11 años de Nagojje la más débil en todos los aspectos.

Las pulpas podrían blanquearse mediante un proceso de cuatro etapas de aplicaciones sucesivas de cloro, hidróxido sódico, hipoclorito sódico y dióxido de cloro, para producir pulpas con una brillantez satisfactoria (86, Mgo = 100), y con unas propiedades de resistencia sólo un poco inferiores a las de las pulpas no blanqueadas.

Pulping characteristics of *Eucalyptus saligna/grandis* growing in Uganda

INTRODUCTION

During the period 1960–70, the Forestry Department in Uganda established experimental plantations of a number of fast-growing species. As part of a programme to determine the utilisation potential of those species with good growth characteristics, the papermaking properties of samples of *Eucalyptus saligna/grandis* have been determined and are reported here.

GROWING CONDITIONS

The samples examined came from two locations; Kajansi Forest Reserve and Nagojje Forest Reserve. The Forest Department, Uganda, provided the following information about these Reserves.

The Kajansi Forest Reserve is situated 9 miles from Kampala on the Kampala-Entebbe road. The site is at an elevation of 930 m. The only climatic feature recorded at the site was rainfall, the mean annual rainfall for 1960–69 being 1,513 mm (range 706 – 2,658 mm); the lowest monthly average was 72 mm in January and August, the highest 230 mm in April. Temperature was not recorded at the site: the mean annual temperature for Kampala was 21°C. The soils are heavy peaty loam overlying waterlogged blue clay; a river running through the plot ensures that the soil is always moist. The plot was established in 1954 using seed collected from local plantations. The initial spacing was approximately 3 m x 3 m and the take-off was satisfactory. One sample, identified as Kajansi Plot 1, was from this plot and the trees were 17 years old when sampled. A second sample was from a nearby plot which was established in 1954, clear-felled in 1962 and regenerated in the same year by coppice and beating up where coppice failed. The trees of the second sample were 9 years old when sampled.

The Nagojje Forest Reserve is situated about 7 miles north of the Kampala-Jjinja road at a point 22 miles from Kampala. The site is at an elevation of 930 m. Again the only climatic information available concerned rainfall: the mean annual rainfall for 1960–70 being 1,648 mm (range 1,290 – 1,938 mm). The lowest monthly average was 68.3 mm in January and the highest 263.3 mm in April. The soil is deep, black, good soil, and has fairly good drainage and is moist most of the time. The plot was established in 1960, using plants from seed originating in Queensland, Australia. The initial spacing was approximately 2.4 m x 2.4 m and the take off was satisfactory. Thinning was carried out in 1963 and 1965. Trees from Nagojje were 11 years old when sampled.

RATE OF GROWTH AND SAMPLING

A representative sample was obtained from a plot of approximately 100 trees. Kajansi Plot 1 was approximately 5,000 m^2 and included 101 trees. Kajansi Plot 2 was approximately 1,900 m^2 and included 125 trees. Nagojje plot was approximately 3,900 m^2 and included 101 trees. The average girth and average height of the trees within each plot is recorded in Table 1. This indicates a fast rate of growth for individual trees, especially in the early years, when height increment exceeded 3 m/year, but the wide differences in stocking density preclude reaching any conclusions about the rate of wood production from the data available.

A sample was obtained from each plot, five trees being selected using random numbers. Dimensions of the sample trees, recorded in Table 1, indicate that the average size of the trees comprising the sample of 9-year-old material from Kajansi was above the average for the plot; that of the 17-year-old sample from Kajansi was below average; and that of the 11-year-old sample from Nagojje was above average. From each selected tree, logs approximately 30 cm long were taken at breast height and 15%, 35% and 65% of the height of the tree, so that each sample consisted of 20 logs. These logs were sent to the United Kingdom and at the Tropical Development and Research Institute (TDRI) they were cut into discs 20 mm thick. One disc from each log was used to determine wood density; the remainder was chipped, using a mechanical guillotine, to provide the material required for chemical analyses and pulping.

EXPERIMENTAL METHODS

Wood density and chemical analyses were carried out in accordance with the standard methods published by TAPPI. Pulping was carried out in a stationary digester with forced circulation and external, electric heating. Pulps were evaluated by forming sheets on a British Standard Sheet machine, and testing them in an atmosphere controlled at 20 ± 1°C, 65 ± 2% relative humidity. The tests were according to the appropriate British Standards, which are generally the same as International and Tappi Standards. Full details of the experimental methods used can be found in the appendix to *Report of the Tropical Products Institute L36* (Palmer and Gibbs, 1974).

Wood density

The density of wood determined as oven-dry weight/green volume, is recorded in Table 2. The average density of the 9-year-old sample from Kajansi was 431 kg/m^3; that of the 17-year-old sample from Kajansi was 467 kg/m^3; and that of the 11-year-old sample from Nagojje was 494 kg/m^3. The variation of density within trees and between trees on the same site was small. Consequently, the differences in density of the samples were probably significant and indicate that wood density would be expected to increase with age, and that growing conditions at Nagojje produced wood with higher density than those at Kajansi.

Chemical analysis

The chemical components which have a major effect on the suitability of wood for pulping were determined and are recorded in Table 3. There were no significant differences between the three samples: the holocellulose content was between 68.6% and 71.1%, the α-cellulose content between 42.1% and 43.0% and the lignin content between 22.8% and 23.6%.

Fibre dimensions

The fibre dimensions, determined by measuring the projected image of fibres from a sulphate pulp, are recorded in Table 4. All three samples yielded short (length, 0.95–1.10 mm), slender (width, 15.8–17.8 μm) and supple (Coefficient of Suppleness, 58–66) fibres. Such fibres would be expected to collapse partially giving an elliptical cross-section and to give good surface contact and fibre/fibre bonding (Istas *et al.,* 1954; Palmer and Gibbs, 1974). The differences recorded were small and unlikely to have a significant effect on the quality of pulp produced. However, the two samples from the Kajansi plantations showed an increase in fibre length and wall thickness, and consequently a small decrease in suppleness, with increasing age; the sample from Nagojje yielded the most slender and least supple fibre.

Pulping and unbleached pulp evaluation

Each sample was pulped by the sulphate process, using two or three different concentrations of reagents. In this way pulps with different yields and lignin content were obtained. Each cook was duplicated and the values reported are the average of the two determinations. Details of the digestion conditions, yield of pulp and a summary of the physical characteristics of the pulp are given in Table 6.

When each sample was pulped using identical conditions (15% active alkali, maximum temperature 170°C), a bleachable pulp was obtained in yields of over 50% and with kappa numbers between 22.3 and 24.8. Differences in yield and kappa number of pulps from the different samples were small and unlikely to prevent commercial pulping of wood from the three samples together. However, there was an indication that the more severe conditions were required to pulp the more dense wood and that the yield of pulp was lowest from the sample from Nagojje. Less severe digestion conditions yielded pulps with higher kappa numbers: the total yield was appreciably higher, but the screened yield only a little higher, indicating that the pulps obtained by less severe digestion conditions were more difficult to disintegrate.

All of the pulps obtained were evaluated by standard techniques, involving beating in a PFI mill, forming sheets in British Standard sheet machine, and testing the conditioned sheets in an atmosphere 20 ± 1°C and 65% relative humidity. Strength characteristics of the pulps at drainability values of 500 and 300 Canadian Standard freeness are given in Table 5, with full evaluations for each pulp in Tables 7 (9-year-old sample from Kajansi), 8 (17-year-old sample from Kajansi) and 9 (11-year-old sample from Nagojje). The 9-year-old sample from Kajansi yielded the pulps with the best bonding properties (breaking length and burst factor); the 17-year-old sample from Kajansi yielded the pulps with the highest tearing strength; and the sample from Nagojje yielded the weakest pulp.

Bleaching and bleached pulp evaluation

One pulp obtained from each sample was bleached using a four-stage sequence of successive treatments with chlorine, sodium hydroxide, sodium hypochlorite and chlorine dioxide. The quantity of chlorine applied in the first stage was varied to allow for differences in the kappa number (residual lignin content) of the pulp: the other stages were constant for all pulps. Full details are given in Table 6. The total quantity of chlorine applied was 9.5% chlorine on oven dry pulp with a kappa number of 22.3 to 10.4% of chlorine on pulp with a kappa number of 24.8. In each case approximately 84% of the chlorine was consumed and the bleached pulp had a brightness of 86 (MgO=100). The yield of bleached pulp was about 5% and its strength properties were about 10% lower than those of unbleached pulps. The brightness (86) was lower than that of many commercial market pulps. However, these results were obtained without determining the optimum bleaching conditions and it is likely that pulps with higher brightness could be obtained by using more complex bleaching sequences and optimised conditions.

COMPARISON WITH PULPS FROM HARDWOODS USED INDUSTRIALLY

Pulps prepared in the laboratory cannot be compared directly with industrial pulps because of differences in operating conditions. Therefore, in order to assess the value of the samples being examined, it is necessary to compare the properties of their pulps with the properties of pulps prepared in the same laboratories from woods used in the pulp industry. In this case chips from mixed hardwoods from the southern USA were used, and details of pulping conditions and the strength characteristics of the pulps obtained summarised in Table 10.

When both the samples of *Eucalyptus* and the US hardwood were pulped using the same conditions, the eucalypts yielded more pulp with a lower kappa number. This indicates that less chemical is required to produce a bleachable grade of pulp from the eucalypts. In general, the strength characteristics of the pulps from the *Eucalyptus* samples were equal to and better than those of the pulps from the US hardwoods. Consequently, it may be concluded that these samples of *Eucalyptus* spp. would be valuable in producing pulps for printing and writing grades of paper and for packaging papers where high tearing strength is not essential.

CONCLUSIONS

1 The density of the wood from the three samples was between 431 kg/m^3 and 494 kg/m^3. The wood density increased with age and there were significant differences with different sites.

2 The holocellulose content of the samples was between 68.6% and 71.1%; the alpha cellulose between 42.1% and 43.0%; and the lignin content between 22.8% and 23.6%.

3 The fibres from these samples were between 0.95 mm and 1.10 mm long and between 15.8 μm and 17.8 μm wide.

4 All samples could be pulped by the sulphate process yielding over 50% of bleachable pulp with good strength characteristics. The pulps could be bleached by a four-stage process (chlorine, sodium hydroxide, sodium hypochlorite and chlorine dioxide) to give bleached pulps with satisfactory brightness (86: MgO = 100) and strength characteristics.

5 These samples of *Eucalyptus grandis/saligna* gave higher yields of stronger pulp than could be obtained from a sample of mixed hardwoods from the southern USA. They could be expected to be used in the production of pulp for printing and writing papers and for packaging papers where high tearing strength is not a critical requirement.

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Table 1

Tree dimensions

Site	Age, years	Within site			Within sample	
		Average girth*, cm	Average height†, m	Average height of largest trees ‡, m	Average girth, cm	Average height, m
Kajansi, Plot 2	9	68.35	30.96	33.75	83.3	32.44
Kajansi, Plot 1	17	123.84	41.1	46.35	112.7	38.44
Nagojje	11	98.91	36.90	39.85	101.9	39.16

Notes: * Average girth determined by measuring the girths of all the trees within the site
† Average height determined by measuring the heights of ten random trees within the site
‡ Average height determined by measuring the heights of the ten trees with the largest girths within the site

Table 2

Wood density

Site	Age, years	Tree identity	Density, kg m^{-3}	
			Range within tree	Tree
Kajansi, Plot 2	9	3	399–457	421
		7	366–464	438
		38	394–460	423
		60	389–455	415
		80	455–481	466
Mean sample value				431
Kajansi, Plot 1	17	4	446–517	471
		34	409–484	437
		42	392–503	448
		78	461–549	514
		79	462–582	517
Mean sample value				467
Nagojje	11	4	465–514	489
		8	442–565	517
		35	468–532	500
		40	427–468	445
		47	466–545	499
Mean sample value				494

Table 3

Chemical analysis

	Kajansi, Plot 2 9-year-old trees	Kajansi, Plot 1 17-year-old trees	Nagojje 11-year-old trees
Ash, %	0.39	0.26	0.30
Silica, %	0.13	0.08	0.12
Alcohol-benzene solubility, %	1.1	1.3	1.5
1% NaOH solubility, %	13.4	13.6	13.6
Holocellulose, %	71.1	70.7	68.6
Alpha-cellulose, %	42.1	43.0	42.6
Lignin, %	22.8	23.3	23.6

Table 4

Fibre dimensions by projection of sulphate pulps

	Kajansi, Plot 2 9-year-old-trees	Kajansi, Plot 1 17-year-old trees	Nagojje 11-year-old trees
Length: all fibres, mm	0.80	0.97	0.87
whole fibres, mm	0.95	1.10	0.96
Width, μm	17.2	17.8	15.8
Wall thickness, μm	3.0	3.4	3.3
Lumen, μm	11.3	10.9	9.1
Coefficient of suppleness	66	61	58

Table 5

Sulphate digestion conditions, unbleached pulp yield and evaluation

	Freeness CSF	Kajansi , Plot 2			Kajansi, Plot 1		Nagojje	
Cook number		MK37	MK22	MK23	MK28	MK25	MK39	MK38
Digestion conditions								
Active alkali as Na_2O on oven-dry wood, %		12.5	15.0	17.5	12.5	15.0	12.5	15.0
Sulphidity, %		25	25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1	1
Time at maximum temperature, h		2	2	2	2	2	2	2
Chemical consumtpion								
Active alkali consumed as Na_20 on oven-dry wood, %		11.5	12.6	14.0	11.5	12.5	11.4	12.9
Yield of pulp								
Yield of oven-dry digested pulp on oven-dry wood, %		53.4	51.9	51.0	54.3	52.7	54.4	50.8
Yield of oven-dry screened pulp on oven-dry wood, %		51.3	51.5	50.9	53.0	52.4	51.4	50.1
Yield of oven-dry screenings on oven-dry digested pulp, %		3.8	0.6	0.1	2.4	0.6	5.6	1.3
Pulp evaluation								
Kappa number		32.3	22.3	21.8	30.1	23.3	33.3	24.8
Bulk, $cm^3\ g^{-1}$	500	1.57	1.59	1.58	1.67	1.62	1.75	1.68
	300	1.37	1.38	1.38	1.47	1.44	1.51	1.49
Burst factor	500	66.5	50.0	46.0	46.5	52.0	45.5	45.5
	300	98.5	80.0	74.0	71.5	77.5	75.5	71.0
Breaking length, km	500	9.7	8.1	7.9	7.9	8.3	7.6	7.5
	300	12.6	11.5	11.7	10.6	10.6	10.4	9.8
Stretch, %	500	3.9	3.4	3.6	3.8	3.7	3.4	3.4
	300	5.7	5.4	5.3	5.4	5.2	5.0	5.0
Tear factor	500	110	105	95	115	110	95	90
	300	115	125	120	140	130	120	120
Double folds	500	430	130	90	140	140	70	50
	300	3 950	3 200	2 600	2 150	2 150	960	880

Table 6

Bleaching conditions, bleached pulp yield and evaluation

	Freeness, CSF	Kajansi, Plot 2	Kajansi, Plot 1	Nagojje
Cook number		MK22	MK25	MK38
Unbleached pulp				
Kappa number		22.3	23.3	24.8
Yield of screened pulp on oven-dry wood, %		51.5	52.4	50.1
Chlorination stage				
Chlorine applied as Cl_2 on oven-dry unbleached pulp, %		5.9	6.3	6.8
Temperature, °C		20	20	20
Time, h		1	1	1
Pulp consistency, %		3	3	3
Chlorine consumed as Cl_2 on oven-dry unbleached pulp, %		4.9	5.3	5.8
Extraction				
Sodium hydroxide on oven-dry unbleached pulp, %		3	3	3
Temperature, °C		60	60	60
Time, h		1	1	1
Pulp consistency, %		6	6	6
Hypochlorite stage				
Sodium hypochlorite applied as available Cl_2 on oven-dry unbleached pulp, %		1	1	1
Temperature, °C		35	35	35
Time, h		2	2	2
Pulp consistency, %		6	6	6
Chlorine consumed as available Cl_2 on oven-dry unbleached pulp, %		0.6	0.6	0.6
Chlorine dioxide stage				
Chlorine dioxide applied as Cl_2 equivalent on oven-dry unbleached pulp, %		2.6	2.6	2.6
Temperature, °C		70	70	70
Time, h		3	3	3
Pulp consistency, %		6	6	6
Chlorine dioxide consumed as Cl_2 equivalent on oven-dry unbleached pulp, %		2.3	2.4	2.4
Summary of bleaching conditions				
Total chlorine applied as Cl_2 on oven-dry unbleached pulp, %		9.5	9.9	10.4
Total chlorine consumed as Cl_2 on oven-dry unbleached pulp, %		7.9	8.3	8.9
Yield of pulp				
Yield of oven-dry bleached pulp on oven-dry unbleached pulp, %		95.5	95.4	95.6
Yield of oven-dry bleached pulp on oven-dry wood, %		49.2	50.0	47.9
Pulp evaluation				
Brightness (MgO=100%), %		86	86	86
Bulk, $cm^3\ g^{-1}$	500	1.59	1.62	1.66
	300	1.38	1.48	–
Burst factor	500	35.0	40.5	38.5
	300	74.0	63.5	–
Breaking length, km	500	6.2	6.7	6.6
	300	10.2	8.8	–
Stretch, %	500	3.0	3.3	3.4
	300	5.1	4.9	–
Tear factor	500	106	96	84
	300	123	129	–
Double folds	500	50	50	35
	300	1 450	740	–
Specific scattering coefficient, $cm^2\ g^{-1}$	500	460	380	380
	300	320	300	–

Table 7

Kajansi, Plot 2, 9-year-old trees: sulphate pulp evaluation

Cook number	Kappa number	Beating time, min.	Freeness, CSF	Drainage time, s	Basis weight, g m^{-2}	Air porosity, s	Thickness, µm	Bulk, cm^3 g^{-1}	Burst factor	Breaking length, km	Stretch, %	Tear factor	Double folds	Bright-ness (MgO= 100%), %	Printing Opacity, %	Specific scattering coefficient, cm^2 g^{-1}
Unbleached																
MK37	32.3	0	600	4.8	61.0	2.6	115	1.89	23.4	5.74	1.9	74	20	25.5		
		1	510	5.3	60.8	11	96	1.58	64.6	9.52	3.8	107	310	22.0		
		3	385	6.2	60.4	37	86	1.43	90.8	11.66	5.0	118	2 324	19.5		
		5	300	7.0	60.4	100	82	1.37	98.9	12.66	5.8	116	3 996	18.0		
MK22	22.3	0	580	4.8	60.4	3.1	114	1.89	20.7	5.03	1.2	58	10	29.5		
		1	480	5.5	60.9	12	94	1.55	53.4	8.57	3.6	108	202	25.0		
		3	380	6.4	60.7	36	86	1.41	71.8	10.72	4.8	117	1 968	22.5		
		5	290	7.6	59.8	96	82	1.38	81.2	11.57	5.6	126	3 422	21.5		
MK23	21.8	0	590	4.8	60.0	2.6	119	1.98	16.8	4.61	1.1	57	5	28.5		
		1	495	5.5	60.1	11	94	1.57	47.0	7.96	3.7	98	102	25.0		
		3	400	6.2	60.2	26	87	1.45	62.1	9.54	4.6	110	751	23.0		
		5	320	7.2	59.9	72	83	1.39	73.0	10.94	5.2	120	2 200	21.5		
Bleached																
MK22		0	590	–	–	–	–	–	–	–	–	–	–	86.5	–	–
		1	475	5.5	60.4	9.0	93	1.54	42.8	7.09	3.4	110	65	84.5	78.5	425
		3	390	6.4	60.0	25	86	1.43	62.4	9.23	4.5	119	450	83.5	74.0	345
		5	290	7.8	60.8	58	83	1.37	75.0	10.29	5.2	124	1 634	82.5	72.5	320

Table 8

Kajansi, Plot 1, 17-year-old trees: sulphate pulp evaluation

Cook number	Kappa number	Beating time, min.	Freeness, CSF	Drainage time, s	Basis weight, $g\ m^{-2}$	Air porosity, s	Thickness, μm	Bulk, $cm^3\ g^{-1}$	Burst factor	Breaking length, km	Stretch, %	Tear factor	Double folds	Brightness (MgO=100%), %	Printing Opacity, %	Specific scattering coefficient $cm^2\ g^{-1}$
Unbleached																
MK28	30.1	0	615	4.8	59.0	1.1	126	2.13	17.4	4.31	1.6	65	8	23.5		
		1	510	5.1	60.2	4.0	102	1.69	44.4	7.67	3.7	111	105	20.0		
		3	400	5.8	61.0	16	93	1.52	62.6	9.75	4.8	138	706	18.5		
		5	255	7.0	60.0	55	88	1.47	74.1	10.80	5.5	140	3 020	17.0		
MK25	23.3	0	625	4.8	60.8	1.1	128	2.10	17.5	4.28	1.3	58	6	25.0		
		1	540	5.1	60.8	4.0	102	1.69	45.2	7.54	3.3	105	80	22.5		
		3	430	5.7	60.8	15	93	1.54	63.0	9.35	4.4	122	481	20.5		
		5	325	6.6	60.5	40	90	1.47	73.4	10.35	5.0	132	1 726	19.5		
Bleached																
MK25		0	590	4.9	60.4	1.1	127	2.10	12.9	3.23	1.4	49	3	85.5	81.5	520
		1	540	5.0	61.2	2.8	104	1.70	31.6	5.78	2.8	84	24	83.0	78.0	405
		3	450	5.6	60.8	8.4	94	1.54	50.1	7.69	4.0	108	134	81.5	75.0	345
		5	340	6.6	60.9	28	89	1.47	61.4	8.68	4.7	125	537	80.5	73.0	310

Table 9

Nagojje, 11-year-old trees: sulphate pulp evaluation

Cook number	Kappa number	Beating time, min.	Freeness, CSF	Drainage time, s	Basis weight, $g\ m^{-2}$	Air porosity, s	Thickness, µm	Bulk, $cm^3\ g^{-1}$	Burst factor	Breaking length, km	Stretch, %	Tear factor	Double folds	Brightness (MgO=100%), %	Printing Opacity, %	Specific scattering coefficient, $cm^2\ g^{-1}$
Unbleached																
MK39	33.3	0	565	4.9	60.4	1.2	126	2.09	18.5	4.78	1.6	60	6	22.5		
		1	500	5.2	60.0	2.8	104	1.75	45.7	7.65	3.4	96	66	18.5		
		3	380	5.8	59.8	12	94	1.57	67.2	9.50	4.4	114	373	16.5		
		5	260	7.1	60.1	41	90	1.49	77.9	10.70	5.2	122	1 291	16.0		
MK38	24.8	0	620	4.8	60.8	1.0	131	2.15	13.9	4.00	1.5	49	4	24.5		
		1	535	5.4	60.6	1.9	106	1.76	38.2	6.76	3.0	81	34	22.0		
		3	425	5.6	61.6	7.6	96	1.56	59.5	8.88	4.2	112	179	19.5		
		5	320	6.4	61.4	22	92	1.49	69.8	9.72	4.9	120	713	19.0		
Bleached																
MK38		0	590	4.8	61.9	0.7	140	2.26	9.6	2.71	1.2	43	2	85.5	83.0	550
		1	555	5.0	61.2	1.6	108	1.77	28.6	5.47	2.6	69	14	83.5	78.5	420
		3	440	5.4	61.3	4.8	96	1.58	47.0	7.52	4.0	98	76	82.5	74.5	345
		5	360	6.0	61.4	13	93	1.51	55.0	8.08	4.2	112	182	81.0	74.0	320

Table 10

US southern hardwoods: sulphate digestion conditions, unbleached pulp yield and evaluation

	Freeness, CSF		
Digestion conditions			
Active alkali as Na_2O on oven-dry wood, %		15.0	17.5
Sulphidity, %		25	25
Maximum temperature, °C		170	170
Time to reach maximum temperature, h		1	1
Time at maximum temperature, h		2	2
Yield of pulp			
Yield of oven-dry digested pulp on oven-dry wood, %		52.0	49.8
Yield of oven-dry screened pulp on oven-dry wood, %		50.9	49.7
Yield of oven-dry screenings on oven-dry digested pulp, %		2.1	0.2
Pulp evaluation			
Kappa number		26.9	23.2
Bulk, $cm^3\ g^{-1}$	500	1.57	1.64
	300	1.46	1.48
Burst factor	500	50	40
	300	63	57
Breaking length, km	500	7.8	7.5
	300	9.6	9.4
Stretch, %	500	4.7	3.8
	300	5.3	4.6
Tear factor	500	140	95
	300	125	115
Double folds	500	430	150
	300	1 800	1 000

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