Tropical Products Institute

L44

Pulping characteristics of *Pinus oocarpa* grown on Mountain Pine Ridge, Belize

Tropical Products Institute

L44

Pulping characteristics of *Pinus oocarpa* grown on Mountain Pine Ridge, Belize

E. R. Palmer and J. A. Gibbs

July 1976

Tropical Products Institute 56/62 Gray's Inn Road London WC1X 8LU
Ministry of Overseas Development

This report was produced by the Tropical Products Institute, a British Government organisation which helps developing countries to derive greater benefit from their renewable resources. It specialises in post-harvest problems and will be pleased to answer requests for information and advice addressed to the Director.

Price £0.60, including packing and postage.
Single copies of this report are available free of charge to public bodies in countries eligible for British aid.

Tropical Products Institute
ISBN: 0 85954 057 X

Contents

Summaries

SUMMARY

Pulping characteristics of *Pinus oocarpa* grown on Mountain Pine Ridge, Belize

A single sample of *Pinus oocarpa* from Mountain Pine Ridge, Belize was pulped by the sulphate process. The results of pulping and pulp evaluation, together with chemical analysis of the wood and fibre dimensions are reported.

The sample consisted of twenty trees selected at random from a naturally regenerating forest. The average age of the trees was estimated as 30 years with a range of 20 to 46 years.

Chemical analysis showed the wood to have an α-cellulose content of 48.9% and a lignin content of 28.7%.

The fibres were 3.13 mm long, 49.8 micrometres wide and had walls 6.9 micrometres thick.

Pulping by the sulphate process yielded between 38% and 44% of unbleached pulp. These yields were lower than usually found in pines.

The pulp had strength characteristics generally similar to those of pulps from Southern Pines of the USA.

Compared with pulps obtained from *P. caribaea* growing in the same area, it was found that *P. oocarpa* gave lower yields of marginally better pulps.

RESUME

Caractéristiques papetières du *Pinus oocarpa* de Mountain Pine Ridge (Belize)

On a fabriqué une pâte au sulfate de *Pinus oocarpa* à partir d'un échantillon provenant de Mountain Pine Ridge (Belize). On donne les résultats de la cuisson, de l'évaluation des caractéristiques des pâtes, de l'analyse chimique du bois et des mesures des dimensions des fibres.

L'échantillon de *Pinus oocarpa* était composé de vingt arbres prélevés au hasard dans une forêt à régénération naturelle. L'âge de ces arbres était compris entre 20 et 46 ans, l'âge moyen étant de 30 ans.

L'analyse chimique a montré que ce bois renferme 48,9% d'α-cellulose et 28,7% de lignine.

Les dimensions des fibres étaient les suivantes:

– longueur: 3,13 mm

– largeur: 49,8 micromètres

–épaisseur des parois des fibres: 6,9 micromètres.

On a obtenu des rendements en pâte au sulfate écrue compris entre 38 et 44%. Les rendements étaient inférieurs à ceux généralement obtenus avec le bois de pin.

La pâte obtenue possédait des caractéristiques mécaniques généralement similaires à celles des pâtes de pin du Sud des Etats-Unis.

La comparaison des pâtes de *Pinus oocarpa* et de *Pinus caribaea* de la même région a montré que le *Pinus oocarpa* donne des pâtes légèrement meilleures avec un rendement plus faible.

RESUMEN

Características de pasteado del *Pinus oocarpa* procedente de Mountain Pine Ridge, Belize

Se pasteó por el proceso al sulfato, una muestra de *Pinus oocarpa* procedente de Mountain Pine Ridge, Belize. Se dá un informe sobre los resultados del pasteado así como una evaluacion de la pasta,- junto con un análisis químico de la madera y las dimensiones de-la fibra.

La muestra pertenecía a veinte aŕboles seleccionados al azar, en un bosque de regeneración natural. La edad media de los árboles-entre los de 20 a 46 años, se calculó en 30 años.

El análisis químico demostró que la madera tenía un contenido de celulosa-α de 48,9% y un contenido de lignina de 28,7%.

La longitud de las fibras era de 3,13 mm y su ancho de 49,8 micrómetros, teniendo sus paredes un espesor de 6,9 micrómetros.

El pasteado por el proceso al sulfato dió un rendimiento de un- 38% y un 44% de pasta sin blanquear. Estos rendimientos eran inferiores a los observados generalmente en los pinos.

Las características de resistencia de la pasta, por lo común,- fueron similares a las de los Pinos del Sur de los Estados Unidos de América.

Comparada con las pastas obtenidas con *P. caribaea,* procedente de la misma zona, se observó que el *P. oocarpa* daba un menor rendimiento de pastas de mejor calidad.

Pulping characteristics of *Pinus oocarpa* grown on Mountain Pine Ridge, Belize

INTRODUCTION

Pinus oocarpa is a very variable and widely distributed species, which is native to Central America, extending through South and West Mexico, Guatemala, El Salvador, Honduras, Nicaragua and Belize. There are four reported varieties. (Dallimore and Jackson, Revised Harrison 1966).

The samples being reported on in this publication came from Mountain Pine Ridge, Belize, and are of *P. oocarpa* var. *ochoterenai.*

P. oocarpa from two localities in the Republic of Honduras was examined in the USA. The report stated that acceptable quality newsprint was made containing 75% *P. oocarpa* groundwood pulp. Promising bond and white wrapping papers were made from bleached sulphate pulp. Experiments to make unbleached papers were less successful but it was suggested that this was due, in part, to the inadequacies of the processing equipment and with correct processing satisfactory papers could be made. (Schafer and Chidester 1961).

The purpose of this investigation was to obtain an indication of the pulping properties of *P. oocarpa* and to compare them with those previously determined for *P. caribaea* from the same area.

SAMPLES

The trees used in this trial were from Plot 8 in Mountain Pine Ridge, Belize. Plot 8 is situated just north of the junction of Little Granite Basin Road and the Salager Line, approximately 16°57'N, 88°54'W, at an altitude of 600 metres. A random selection of twenty trees was made. Logs were cut at each 10% of the height of each tree. Most of this material was used in anatomical studies at the Commonwealth Forestry Institute, but one disc from each log was sent to the Tropical Products Institute for pulping studies.

The trees came from a stand of natural regeneration; therefore the age of the trees in this sample was not known but the average age was estimated as 30 years with the range for individual trees from about 20 years to about 46 years. The average height of the trees was 20 metres with a range of 16.5 to 27 metres.

To obtain a sample from each disc for density determination, two segments, amounting together to one third of the volume, were cut from opposite sides. The density of each piece was determined and the mean density for tree and site calculated by weighting the results obtained for the size of the disc.

The single sample for the pulping trial was obtained by mixing the remaining portions of the disc, weighted for their size, so that a sample representative of the site was obtained.

EXPERIMENTAL RESULTS AND DISCUSSION

Full details of the experimental techniques and the methods of calculating results are given in the appendix.

Throughout this report comparisons are made with results for pulping *P. caribaea* from Mountain Pine Ridge, Belize. These results are taken from a study of *P. caribaea* from twelve sites in Belize carried out in this Institute and previously published (Palmer and Gibbs 1976). Two of these samples were received from Mountain Pine Ridge; one, from a site at 600 metres elevation, had an estimated age of 18 to 20 years; the second, from a site at 500 metres elevation, had an estimated age of 15 years.

Density

The density of the wood expressed as $\frac{\text{oven dry weight}}{\text{green (soaked) volume}}$ is given in Table 1.

Table 1

Pinus oocarpa **from Belize**

Apparent density: $\frac{\text{oven dry weight}}{\text{green (soaked) volume}}$

Tree number	Average density kg/m^3	Lower and upper limits of density within tree kg/m^3
1	620	530–850
4	510	315–630
5	505	400–540
7	435	350–540
9	515	410–590
11	600	535–625
12	485	420–535
13	510	315–570
26	495	420–525
33	475	410–550
35	580	510–650
39	540	495–575
42	525	420–630
45	540	425–640
52	500	390–565
55	495	420–560
61	615	465–740
73	535	455–620
92	525	440–610
96	510	445–575

Mean Value for site 530 kg/m^3

The mean density for all the trees in the sample was 530 kg/m^3. This density was of the same order as the densities of natural growth and the older plantations of *P. caribaea* in Belize. It was, also, towards the upper end of the range of the densities of coniferous trees commonly used for pulping.

The range of average densities for individual trees on the site (435 to 610 kg/m^3) was smaller than that usually found on natural sites of coniferous species in the tropics. The variation of density within a single tree was often greater than the variation of averages between trees. The upper part of the tree usually had a lower density than the lower parts.

Chemical analysis

The more important chemical constituents affecting the pulping of wood were determined with the following results:

Table 2

Chemical Composition of *P. oocarpa* and *P. caribaea* from Mountain Pine Ridge, Belize

	P. oocarpa	*P. caribaea*	
		Site at 600 m	Site at 500 m
(a) Determined on original wood			
Alcohol-Benzene extractives	3.8	1.6	1.3
1% NaOH solubility	15.1	12.5	12.0
Expressed as percentage of oven dry wood.			
(b) Determined on sample previously extracted with successive treatments of alcohol-benzene, alcohol and hot water			
Holocellulose	67.5	63.8	62.4
α-cellulose	48.9	44.4	43.5
Lignin	28.7	27.3	27.6
Expressed as percentage of oven dry extractive-free wood.			

Although the higher alcohol-benzene solubles and lignin content indicated that *P. oocarpa* might require slightly more severe pulping conditions than *P. caribaea,* nothing indicated that any special problems could be expected with sulphate pulping.

Fibre dimensions

(Note: In the strict botanical sense the elements measured were tracheids, but we have followed the most common pulp and papermaking practice in calling them "fibres".)

The length, width and wall thickness of the fibres was determined using fibres from a well-digested sulphate pulp. The results were:

Table 3

Fibre Dimensions of *P. oocarpa* and *P. caribaea* from Mountain Pine Ridge, Belize

	P. oocarpa		*P. caribaea*			
			Site at 600 m		Site at 500 m	
Fibre length, whole fibres only, mm	3.13	(0.16)	3.54	(0.11)	3.58	(0.10)
Fibre length, all fibres, mm	2.74	(0.17)	2.80	(0.12)	2.89	(0.12)
Width, μm	49.8	(1.3)	48.7	(0.7)	47.8	(0.9)
Wall thickness, μm	6.9	(0.3)	6.1	(0.2)	5.6	(0.2)

Note: The figure in parenthesis is the standard error of the mean for each determination.

These results indicated that the fibres of *P. oocarpa* were long and coarse. The thick cell walls indicated that the fibres were not very flexible and therefore it might be difficult for the fibres to become well-bonded in a sheet of paper. Consequently, it was not expected that pulps from *P. oocarpa* would have the highest strength properties.

The fibres from the samples of *P. caribaea* were longer and more flexible, but not sufficiently different to expect any major difference in pulp quality.

Pulping and pulp evaluation

The sample was pulped by the sulphate process using several different conditions to produce a range of pulps. Details of pulping conditions, yield of pulps and a summary of the pulp quality are given in Table 4. Full pulp evaluation data for unbleached pulps are given in Table 6.

Table 4

Pinus oocarpa from Belize (Mountain Pine Ridge)

Preparation and evaluation of unbleached sulphate pulps

Cook Numbers		K341	K375	K374	K376
Digestion conditions					
Active Alkali, as Na_2O% oven dry wood		22.5	17.5	20.0	22.5
Sulphidity, %		25	25	25	25
Liquor to oven dry wood ratio		6:1	6:1	6:1	6:1
Maximum temperature, °C		165	170	170	170
Time to reach maximum temp. hrs.		1	1	1	1
Time at maximum temp. hrs.		4	4	4	4
Active Alkali consumed as Na_2O% oven dry wood		12.9	13.7	14.1	14.1
Yield, oven dry digested pulp % oven dry wood		44.1	41.9	38.0	39.0
Screening on 0.15 mm slots					
Rejects, oven dry rejects % oven dry pulp		0.5	3.7	1.4	0.5
Yield, oven dry screened pulp % oven dry wood		43.9	40.3	37.4	38.8
Pulp characteristics					
Kappa Number of screened pulp		28.8	33.5	25.4	19.4
Bulk cm^3/g	500 CSf	1.57	1.69	1.67	1.59
	300 CSf	1.50	1.60	1.60	1.53
Burst Factor	500 CSf	52	51	47	40
	300 CSf	57	57	52	45
Breaking length km	500 CSf	7.7	7.5	7.0	6.5
	300 CSf	8.1	8.2	7.5	7.3
Tear Factor	500 CSf	200	150	150	140
	300 CSf	185	140	140	130
Double Folds	500 CSf	3200	1900	1650	1550
	300 CSf	3650	2400	2200	1950

No difficulty was experienced in producing the pulp. The yield of pulp of 38 to 44% was a little lower than expected. There appeared to be some advantage in improved pulp yield and higher pulp strength properties to be obtained by digestion at a lower temperature.

Bleaching trials

Two of the pulps with lower kappa numbers were bleached using a four stage process of chlorination, alkali extraction, hypochlorite and chlorine dioxide. Details of the bleaching conditions and a summary of bleached pulp quality are given in Table 5; full evaluation of bleached pulps are in Table 7.

Commercial bleaching processes usually use more than four stages; consequently the relatively simple four stage process would not be expected to produce a fully bleached pulp. The brightness obtained in this trial (80, MgO = 100) is reasonable for the process used and higher brightness should be obtained with more complex procedures.

The strength characteristics of the bleached pulps were similar to those of the unbleached pulps from which they were prepared.

Comparison with commercial pulpwoods

In order to assess the potential value of pulps made from *P. oocarpa,* they were compared with pulps made in this laboratory from woods commonly used in commercial pulping. The results of evaluating unbleached pulps from four commercially used woods are given in Table 8.

Table 5

***Pinus oocarpa* from Belize (Mountain Pine Ridge)**

Preparation and evaluation of bleached pulps

Cook Number		K341	K376
Kappa number of unbleached pulp		28.8	19.4
Bleaching conditions			
(1) Chlorination Chlorine added % oven dry unbleached pulp Conditions: 1 hr, 20°C, 3% pulp consistency		8.1	5.0
(2) Alkali extraction NaOH% on oven dry unbleached pulp Conditions: 1 hr, 60°C, 6% pulp consistency		3	3
(3) Sodium hypochlorite Available chlorine as Cl_2% on oven dry unbleached pulp Conditions: 2 hrs, 35°C, 6% pulp consistency		1	1
(4) Chlorine dioxide as Cl_2% oven dry unbleached pulp Conditions: 3 hrs, 70°C, 6% pulp consistency		2.6	2.6
Total chlorine added % oven dry unbleached pulp		11.7	8.6
Total chlorine consumed % oven dry unbleached pulp		10.8	7.7
Yield of bleached pulp % oven dry wood		41.5	35.9
Bleached pulp characteristics			
Brightness, Elrepho 457 nm filter MgO = 100		80	80
Bulk cm^3/g	500 CSf	1.6	1.6
	300 CSf	1.5	1.5
Burst Factor	500 CSf	52	36
	300 CSf	59	39
Breaking length, km	500 CSf	7.4	6.2
	300 CSf	8.2	6.8
Tear Factor	500 CSf	195	130
	300 CSf	180	120
Double Folds	500 CSf	3800	650
	300 CSf	3700	700
Specific Scattering Co-efficient	500 CSf	165	175
	300 CSf	155	165

The yield of pulp from *P. oocarpa* was lower than the yield of pulp of similar kappa numbers (residual lignin content) obtained from other pulpwoods.

Overall the pulps from *P. oocarpa* had poorer tensile and bursting strengths than, and similar tearing strengths to, the pulps obtained from two samples of temperate pines and poorer tensile and bursting strengths and better tearing strengths than pulps from two samples of spruce. The pulps from *P. oocarpa* were more like pulps obtained from Southern Pines from the USA and it is likely that they could be used in similar products.

The evaluation of bleached pulps obtained from two commercially used pines are given in Table 9.

The yield of bleached pulp from *P. oocarpa* was lower than that obtained from either of the other samples; the brightness of the pulps from *P. oocarpa* was marginally lower; the strength properties of the pulp from *P. oocarpa* were more like those of pulps from Southern Pines from USA, than those of the more northerly grown *P. sylvestris.*

Comparison with pulps from *P. caribaea* grown on Mountain Pine Ridge, Belize

Details of the digestion conditions of two samples of *P. caribaea* grown on Mountain Pine Ridge, Belize, are given in Table 10 together with a summary of

the unbleached pulp evaluation. Full pulp evaluation data for these two samples are given in Tables 11 and 12.

When cooked using similar digestion conditions pulps from both species had kappa numbers nearly the same, but the yield of pulp from *P. oocarpa* was appreciably lower than that from the two *P. caribaea* samples.

Comparing pulps with the same kappa number, pulps from both species had similar tearing strength but that from *P. oocarpa* had appreciably better tensile and bursting strengths.

Neither of these findings would have been predicted from the chemical analysis and fibre dimensions. Chemical analysis indicated that *P. oocarpa* would be slightly more difficult to pulp but would yield a little more pulp. Fibre dimensions indicated that pulps from *P. oocarpa* would be expected to have the poorer tensile and bursting strengths.

However, it is unwise to read too much into these findings. The differences between the pulps of the two species were of the order of 10%. Although both the samples had been selected to be representative of the area in which they were growing, different techniques were used which may have contributed to this difference. A more important difference was age; the *P. oocarpa* samples had an average age of 30 years, whereas both the *P. caribaea* samples were under 20. In general an older sample might be expected to have better yield, higher tearing strength, but lower tensile and bursting strengths than a young sample. If this relationship held for these two species, at equal age the tensile and bursting strengths would be expected to be even further in favour of *P. oocarpa* whilst the yield would be further in favour of *P. caribaea.*

Assuming that the cost of wood of both species was the same, pulp from *P. oocarpa* would be expected to be more expensive because of higher raw material costs, but the pulp would have better strength characteristics than pulp from *P. caribaea.* The better strength characteristics are unlikely to increase the value of the pulp sufficiently to compensate for higher production costs.

CONCLUSIONS

(1) A single sample of *P. oocarpa* was pulped. The sample consisted of 10 discs from each of twenty trees selected at random from a naturally regenerated forest on the Mountain Pine Ridge, Belize. The average age of the trees was 30 years with a range of 20 to 46 years.

(2) The average density of the sample was 530 kg/m^3. This was similar to the density of trees of *P. caribaea* in older plantations or naturally grown in Belize and at the upper end of the range of the density of coniferous trees commonly used for pulping.

(3) Chemical analysis indicated that there should be no special problems in digestion by the sulphate process. The sample was pulped without difficulty.

(4) Fibre dimensions showed a long, coarse, stiff fibre which indicated that pulps were unlikely to have the highest strength characteristics. In fact the pulps obtained were of moderate strength.

(5) When pulped by the sulphate process yields of between 38 and 44% were obtained; the yields were lower than would be expected from most coniferous pulpwoods. There was an indication that both pulp yield and strength properties were improved by pulping at a slightly lower temperature.

(6) Unbleached pulps were similar to those obtained in this laboratory from Southern Pines of the USA. The tensile and bursting strengths were a little lower, the tearing strength about the same.

(7) Two pulps were bleached by a four stage process of chlorination, alkali extraction, hypochlorite and chlorine dioxide. The brightness of the bleached pulps was similar to that obtained using the same techniques on other samples of pines; the other optical properties and the strength properties were similar to those of bleached pulps obtained from Southern Pines of the USA.

(8) When compared with pulps obtained from *P. caribaea* grown on Mountain Pine Ridge, it was found that *P. oocarpa* yielded less pulp but the pulp from both species had similar tearing strength and that from *P. oocarpa* had the higher tensile and bursting strength. It was thought to be unlikely that the slightly higher quality would compensate for the lower yield.

References

DALLIMORE, W. and JACKSON, A. B. (Revised by HARRISON, S. G.) (1966) A handbook of Coniferae and Ginkgoaceae. London: Edward Arnold (Publishers) Ltd., 4th edition.

PALMER, E. R. and GIBBS, J. A. (1976) Pulping characteristics of *Pinus caribaea* from Belize. *Rep. Trop. Prod. Inst.* L43, iv + 43.

SCHAFER, E. R. and CHIDESTER, G. H. (1961) Pulping and papermaking experiments on certain pines of Mexico and Central America. *Rep. US For. Prod. Lab.* No. 2217, pp. 34.

Table 6

Pinus oocarpa **from Belize**

Unbleached sulphate pulp evaluation

Beaten in P.F.I. Mill

Cook number	Kappa number	Yield per cent oven dry wood		Beating time mins	Canadian Standard freeness	Drainage time secs	Basis weight g/m^2	Air Porosity 100 cm^3/6.45 cm^2 sec	Thickness microns	Bulk cm^3/g	Burst factor	Breaking length metres	Stretch per cent	Tear factor	Double folds Kohler-Molin 7.85 N
		Total	Screened												
K341	28.8	44.1	43.9	0	770	4.3	59.7	0.1	154	2.577	8.0	1 855	1.7	108	4
				2	725	4.4	58.6	0.2	103	1.756	35.7	5 965	4.9	225	1 620
				4	630	4.6	58.1	1.3	96	1.655	45.8	7 042	5.1	217	2 535
				6	490	4.8	59.6	18.8	93	1.564	52.1	7 709	5.1	201	3 209
				8	275	6.1	60.6	198.8	91	1.496	57.7	8 181	5.2	183	3 695
				10	185	10.5	60.0	983.9	88	1.458	60.0	8 689	4.7	175	4 063
				12	75	36.1	59.3	over 1 000	82	1.385	66.0	9 357	4.3	162	4 206
K375	33.5	41.9	40.3	0	755	4.3	63.5	less than 0.1	183	2.888	9.4	2 017	2.1	105	6
				2	750	4.4	61.2	0.2	115	1.879	31.0	5 320	4.4	157	689
				4	640	4.5	59.4	1.2	102	1.720	46.3	6 968	5.1	163	1 633
				6	390	4.8	59.2	30.2	98	1.652	54.7	8 015	5.0	142	2 251
				8	245	5.8	58.8	220.2	92	1.573	57.6	8 430	4.3	138	2 664
				10	120	11.5	57.5	over 1 000	88	1.529	64.0	8 982	3.8	134	2 978
				12	65	33.6	58.1		83	1.424	66.9	9 462	3.8	134	4 143
K374	25.4	38.0	37.4	0	760	4.4	59.9	less than 0.1	175	2.925	8.5	2 123	1.8	95	2
				2	735	4.5	63.0	0.3	111	1.769	30.9	5 314	4.8	162	536
				4	580	4.7	60.1	2.8	102	1.695	44.9	6 851	4.4	155	1 422
				6	295	5.3	60.5	71.9	96	1.594	52.5	7 532	4.4	137	2 202
				8	165	8.3	59.6	794.7	90	1.518	55 0	8 067	3.6	131	2 075
				10	80	22.6	59.2	over 1 000	87	1.466	59.0	8 626	3.8	120	3 292
K376	19.4	39.0	38.8	0	760	4.3	61.5	0.1	177	2.878	9.1	2 281	2.0	98	3
				2	725	4.4	60.3	0.3	107	1.780	25.3	4 747	3.8	149	158
				4	550	4.6	59.2	3.9	95	1.609	38.3	6 309	4.0	142	1 438
				6	250	5.9	57.4	222.9	87	1.512	46.2	7 498	3.7	131	2 037
				8	115	14.0	57.9	over 1 000	83	1.429	51.6	8 048	3.9	119	2 374
				10	60	43.5	57.2		79	1.383	55.2	8 807	3.7	106	2 698

Table 7

Pinus oocarpa **from Belize**

Bleached sulphate pulp evaluation

Beaten in P.F.I. Mill

Cook number	Kappa number of un-bleached pulp	Total chlorine applied per cent oven dry un-bleached pulp	Yield of bleached pulp per cent oven dry wood	Beating time min	Canadian Standard freeness	Drainage time secs	Basis weight g/m^2	Air porosity 100 cm^3/ 6.45 cm^2 sec	Thick-ness microns	Bulk cm^3/g	Burst factor	Breaking length metres	Stretch per cent	Tear factor	Double folds Kohler Molin 7.85 N	Brightness Elrepho 457 nm filter MgO = 100	Printing opacity per cent	Specific scattering co-efficient
K341	28.8	11.7	41.5	0	760	4.3	60.5	0.1	172	2.841	6.6	1 593	1.8	92	2	80	72	315
				2	715	4.4	60.0	0.4	106	1.761	37.2	5 893	4.8	225	1 891		61	205
				4	600	4.5	59.3	1.9	97	1.643	48.4	7 091	5.3	197	3 612		59	170
				6	370	4.9	59.6	26.9	91	1.536	57.6	7 908	5.1	186	3 979		57	155
				8	220	6.6	58.8	274.7	88	1.491	59.8	8 425	5.1	173	3 516		56	155
				10	105	15.1	58.5	over 1 000	83	1.422	65.1	9 366	4.3	174	5 243		55	140
K376	19.4	8.6	35.9	0	750	4.4	61.5	less than 0.1	169	2.754	8.9	2 184	2.4	111	3	80	73	305
				2	725	4.4	58.1	0.3	102	1.765	25.1	4 707	4.2	160	98		63	205
				4	540	4.6	59.4	3.0	94	1.576	35.0	6 040	4.3	134	645		61	175
				5	315	5.1	59.5	58.3	89	1.490	39.5	6 784	4.3	124	697		59	165
				6	200	6.5	58.0	273.9	84	1.444	42.0	7 317	3.9	119	976		57	155
				8	110	14.4	58.7	over 1 000	82	1.406	45.5	7 406	4.1	105	1 241		58	150

Table 8

Comparative laboratory-made unbleached sulphate pulps from various commercial pulpwoods

Physical characteristics interpolated at 500 and 300 CSf

Species	Kappa number	Yield of unbleached pulp per cent oven dry wood		Canadian Standard freeness	Bulk cm^3/g	Burst factor	Breaking length, km	Tear factor
		Total	Screened					
Pinus sylvestris, UK grown	72.4	52.7	46.7	500	1.57	64	9.2	175
				300	1.50	69	9.8	155
	54.6	48.1	45.8	500	1.50	75	10.4	165
				300	1.48	79	10.9	155
	36.0	45.5	45.2	500	1.47	70	10.0	165
				300	1.40	74	10.5	155
	27.2	43.4	43.4	500	1.49	62	9.4	165
				300	1.44	67	10.1	155
Mixed Southern Pines, USA grown	52.3	49.0	48.5	500	1.60	61	8.6	175
				300	1.53	67	9.5	165
	40.8	45.5	45.1	500	1.53	60	8.5	185
				300	1.50	64	9.0	175
	22.6	43.7	43.2	500	1.59	41	7.0	100
				300	1.53	44	7.4	90
Picea sitchensis, UK grown	54.0	50.7	48.6	500	1.32	79	11.2	110
				300	1.27	82	11.6	105
	33.0	44.3	43.9	500	1.40	59	9.1	95
				300	1.35	64	10.0	85
	22.3	42.6	42.4	500	1.39	50	8.1	80
				300	1.34	54	8.9	75
Spruce, USA grown	87.2	56.4	54.8	500	1.36	94	12.8	115
				300	1.32	100	13.0	100
	55.6	50.7	50.3	500	1.44	83	11.5	140
				300	1.38	92	12.4	130
	23.2	43.5	43.5	500	1.35	56	9.1	90
				300	1.30	60	9.6	85

Table 9

Comparative laboratory-made bleached sulphate pulps from commercial pulpwoods

Bleaching stages: C-E-H-D

Physical characteristics interpolated at 500 and 300 CSf

Country or origin and species	Kappa number of unbleached pulp	Yield of oven-dry bleached pulp, per cent oven-dry wood	Brightness (unbeaten), Elrepho 457 nm, MgO = 100	Canadian Standard freeness	Bulk, cm^3/g	Burst factor	Breaking length, km	Tear factor	Specific scattering coefficient
UK, *Pinus sylvestris*	27	41.4	81	500	1.43	60	9.1	162	205
				300	1.39	67	9.9	147	180
USA, Southern Pines	24	42.0	82	500	1.50	48	7.7	150	175
				300	1.46	51	8.1	136	164

Table 10

Pinus caribaea from Belize (Mountain Pine Ridge)

Preparation and evaluation of unbleached pulp

Site		Mountain Pine	Mountain Pine	Mountain Pine	Mountain Pine
Date of planting		Site at 600 m Natural regeneration	Site at 500 m Natural regeneration	Site at 600 m Natural regeneration	Site at 500 m Natural regeneration
Cook number		K462	K464	K463	K465
Digestion conditions					
Active Alkali as Na_2O% oven dry wood		17.5		20	
Sulphidity		25		25	
Liquor to oven-dry wood ratio		6:1		6:1	
Maximum temperature, °C		170		170	
Time to reach maximum temperature, hours		1		1	
Time at maximum temperature, hours		4		4	
Chemical consumption					
Active Alkali consumed as Na_2O% oven dry wood		13.6	14.0	14.0	14.4
Yield of pulp					
Yield of oven dry digested pulp % oven dry wood		45.8	46.0	43.5	42.5
Yield of oven dry screened pulp % oven dry wood		44.5	44.6	43.3	42.0
Yield of screenings (on 0.15 mm slits) % oven dry digested pulp		2.8	2.9	0.4	1.1
Pulp evaluation					
Kappa number of screened pulp		37.3	35.7	24.5	26.8
Beating time in P.F.I. Mill, mins	500 CSf	4.0	4.0	3.6	3.4
	300 CSf	6.0	5.7	5.1	5.1
Bulk, cm^3/g	500 CSf	1.73	1.71	1.69	1.67
	300 CSf	1.67	1.65	1.63	1.59
Air porosity, 100 cm^3/6.45 cm^2, secs	500 CSf	4	5	5	5
	300 CSf	50	50	60	70
Breaking length, km	500 CSf	6.5	6.5	6.0	5.9
	300 CSf	7.2	7.2	6.7	6.5
Burst factor	500 CSf	45	46	40	38
	300 CSf	53	52	44	44
Tear factor	500 CSf	169	147	138	123
	300 CSf	158	139	133	120
Double folds, Kohler-Molin, 7.85 N	500 CSf	1 650	1 440	870	870
	300 CSf	1 950	1 900	1 320	1 110

Table 11

Pinus caribaea **from Mountain Pine Ridge site at 600 m elevation**

Unbleached sulphate pulp evaluation

Beaten in P.F.I. Mill

	Beating time, min	Canadian Standard freeness	Drainage time, sec	Basis weight g/m^2	Air porosity 100 cm^3/ 6.45 cm^2 sec	Thickness microns	Bulk cm^3/g	Burst factor	Breaking length metres	Stretch per cent	Tear factor	Double folds Kohler-Molin 7.85 N
K462	0	750	4.4	64.2	0.1	180	2.81	8.4	1 972	1.9	120	4
Yield of screened pulp 44.5%	1	735	4.4	60.6	0.2	114	1.88	28.4	4 804	4.3	199	397
Kappa Number 37.3	2	695	4.4	59.3	0.4	106	1.79	36.5	5 579	4.8	202	789
	3	615	4.4	60.5	1.3	106	1.76	41.0	6 078	5.1	167	1 341
	4	500	4.5	60.4	4.3	104	1.72	45.0	6 408	4.6	167	2 115
	5	390	4.8	60.0	15.0	102	1.70	50.7	6 830	4.6	167	1 920
	6	290	5.2	60.2	54.3	100	1.67	51.6	7 150	4.6	161	1 917
K463	0	765	4.4	61.6	0.1	161	2.61	9.6	2 169	2.4	117	7
Yield of screened pulp 43.3%	1	735	4.4	60.8	0.2	114	1.88	25.1	4 315	4.1	145	120
Kappa Number 24.5	2	695	4.5	61.1	0.7	107	1.76	32.8	5 148	4.4	144	283
	3	560	4.6	59.2	2.3	102	1.73	39.0	5 953	4.2	144	789
	4	440	4.8	60.1	9.2	100	1.66	41.3	6 092	4.0	140	961
	5	310	5.4	58.9	50.6	96	1.63	45.0	6 861	3.7	130	1 215
	6	205	6.3	59.4	209	93	1.57	45.0	7 015	3.6	131	1 596

Table 12

Pinus caribaea **from Mountain Pine Ridge site at 500 m elevation**

Unbleached sulphate pulp evaluations

Beaten in P.F.I. Mill

	Beating time min	Canadian Standard freeness	Drainage time sec	Basis weight g/m^2	Air porosity 100 cm^3/ 6.45 cm^2 sec	Thick-ness microns	Bulk cm^3/g	Burst factor	Breaking length metres	Stretch per cent	Tear factor	Double folds Kohler Molin 7.85 N
K464	0	750	4.4	59.6	0.1	164	2.75	8.9	1 937	2.0	118	5
Yield of screened pulp 44.6%	1	745	4.4	60.0	0.2	115	1.92	27.0	4 326	4.2	147	259
Kappa Number 35.7	2	695	4.5	59.7	0.6	106	1.78	36.8	5 632	4.4	150	728
	3	615	4.5	60.4	1.8	106	1.75	42.8	6 053	4.3	151	1 376
	4	500	4.6	60.3	5.1	102	1.70	45.3	6 388	4.4	147	1 389
	5	375	5.0	60.4	22.5	100	1.66	50.1	6 783	4.5	139	1 791
	6	280	5.4	60.1	73.4	100	1.66	49.3	7 271	4.4	143	1 953
K465	0	760	4.4	60.6	0.1	156	2.57	10.7	2 294	3.3	121	8
Yield of screened pulp 42.0%	1	735	4.4	60.0	0.3	110	1.84	25.9	4 337	4.0	140	113
Kappa Number 26.8	2	670	4.5	60.5	0.9	106	1.74	32.8	5 318	4.4	131	435
	3	555	4.6	59.8	3.4	101	1.69	36.4	6 042	4.0	124	947
	4	420	4.7	59.7	12.8	98	1.64	40.6	6 103	4.0	120	922
	5	310	5.4	61.1	68.6	97	1.59	44.4	6 478	4.0	124	1 238
	6	220	6.3	60.6	289.7	93	1.54	44.1	6 622	4.0	114	919

Bleached pulp evaluations

													Brightness Elrepho 457 nm filter MgO = 100	Printing Opacity	Specific Scattering Co-efficient
K465	0	740	4.4	60.6	0.1	168	2.77	7.0	1 628	1.7	94	2	80	73	315
Yield of bleached pulp 39.9%	1	710	4.5	61.1	0.5	113	1.85	25.7	4 062	4.3	136	77	75	65	210
	2	665	4.6	61.7	0.5	109	1.77	24.3	4 309	3.7	137	58	74	64	196
	3	550	4.6	61.1	0.9	104	1.71	31.9	5 010	4.5	126	230	74	61	183
	4	370	5.1	60.5	17.9	96	1.60	38.6	6 052	3.3	119	502	72	57	154
	5	220	6.2	59.2	186.7	93	1.57	43.7	6 560	3.8	120	823	72	56	150
	6	150	8.0	60.0	646.6	89	1.48	42.7	6 660	3.7	101	930	71	56	145

Appendix

EXPERIMENTAL METHODS IN PULPING INVESTIGATIONS

1. Apparent density of wood

The method used was TAPPI Standard method T 18 m–53 using one piece approximately 2.5 cm (1.0 in) thick from each log received.

The green volume was determined by weighing the disc, which had been soaked in water until it was saturated, immersed in water. The oven-dry weight was determined by weighing the disc after it had been dried to constant weight at 105° ± 3°C.

The apparent density is expressed as: $\frac{\text{oven-dry weight}}{\text{green (soaked) volume}}$

2. Chemical analysis

The chemical analyses were carried out on a composite sample. A portion of the chips prepared for pulping trials were ground in an Apex knife mill and the fraction of groundwood which passed through a British Standard 40 mesh (420 μm) sieve and was retained on a British Standard 60 mesh (250 μm) sieve was used for analysis.

The methods used were:

Alcohol-benzene solubility	TAPPI T 6 m–59
Holocellulose	Wise, Murphy, D'Addieco
Alpha-cellulose	TAPPI T 203 os–61
1% caustic soda solubility	TAPPI T 4 m–59
Lignin	TAPPI T 13 m–54

The fractions soluble in alcohol-benzene and 1% caustic soda are expressed as oven-dry extractives per cent oven-dry wood.

The alpha-cellulose and lignin (oven-dry) are expressed as per cent oven-dry wood.

The holocellulose cellulose was dried by washing in acetone and storing at room temperature in a desiccator until constant weight. Under these conditions the holocellulose was found to have a moisture content of 2%. In calculating the result allowance was made for this moisture content and the result is reported as oven-dry holocellulose per cent oven-dry wood.

3. Microscopic examination

The fibre measurements were made on re-dispersions of pieces of standard sheets made from unbeaten sulphate pulp and they are thus representative of a composite sample. The fibres were mounted in aqueous medium and the length, width and wall thickness of 400 fibres measured. The lengths of all fibre elements both

whole and broken were determined by measuring a projected image. In this way the average length of fibres in the pulp and a distribution curve of lengths were obtained. The widths of the partially collapsed fibres and the wall thickness were determined by direct measurement of the projected image. Because pulping and the pressing during sheet making causes the fibres to collapse the widths are typical of the pulp only. Fibre wall thickness as measured may also differ from that observed on a cross-section of wood.

The fibre length by classification was determined using a Bauer-MacNett classifier and weighing the fibres retained on each screen. In previous work the average length of the fibres on each screen had been determined and the values were used in estimating the average length.

4. Pulping methods

The chips used for pulping were prepared by sawing the log into discs approximately 18 mm thick and then splitting along the grain with a mechanical guillotine to give a chip approximately 18 x 6 mm thick. This damages the fibres less than commercial chipping.

Laboratory pulping was carried out in an electrically-heated, stainless steel, rotating pressure vessel. The method used was the sulphate (Kraft) process, which was selected as being the most promising process for use on tropical woods in tropical conditions. The active chemicals are sodium hydroxide and sodium sulphide.

The concentration of chemicals is calculated according to the following definitions:

(a) Active alkali = $NaOH + Na_2S$ expressed as Na_2O per cent on oven-dry wood.

(b) Sulphidity = $\frac{Na_2S \times 100}{NaOH + Na_2S,}$ all the compounds expressed as Na_2O.

A sulphidity of 25 per cent was used in each of these experiments, chosen because published information shows there to be generally little variation in pulp quality with charges in sulphidity in the range of 20 to 30%.

The cooked chips were washed free of superficial black liquor and broken up in a propeller type disintegrator to simulate the disintegration occurring during blowing a commercial digester; the pulp was screened using a plate with 0.15 mm wide slits, to remove shive, and collected on a 150 mesh sieve.

The yield of pulp was determined by drying the whole of the screened pulp in a stream of air to about 10% moisture. The total weight of air-dry screened pulp and the moisture content of an aliquot were determined for calculating the yield of oven-dry pulp.

The total alkali in the black liquor was determined by titrating an ashed aliquot of black liquor with hydrochloric acid. The active akali remaining was determined by titrating an aliquot of black liquor after removing the sodium salts which are the reaction products of digestion by precipitation with barium chloride. The active alkali consumed was the difference of these results.

5. Unbleached pulp evaluation

The Kappa number was determined by TAPPI standard method T 236 m–60. The method is identical with the International Committee for Chemical Analyses Method ICCA 1:59 which has been adopted throughout the world.

The amount of permanganate consumed by pulp under specified conditions is measured and, for pulp yields of less than 70%, the percentage of Klason lignin approximately equals Kappa number X0.15.

The pulp was evaluated by preparing and testing standard sheets, from pulp which had been air-dried, according to the proposals of the 'Second Report of the Pulp

Evaluation Committee to the Technical Section of the (British) Papermakers' Association'.

The sheets of approximately 60 g/m^2 were tested after conditioning at 20 ± 1°C and 65% relative humidity. The methods given in this report are practically identical with those in TAPPI Standard T 205 m–58. The effect of air-drying is to lower the strength of the unbeaten pulp, but, except for specific scattering coefficient, the effect on beaten pulps is small.

The pulps were beaten in a PFI mill using a pulp consistency of 10%, a beating pressure of 17.7 N per cm of bar length and a difference between the peripheral speeds of the beating elements of 2 m/s.

The methods used for the physical examination of each set of sheets were:

(a) Thickness: Ten measurements made on ten sheets placed one on top of another using a dead weight micrometer.

(b) Breaking length and stretch: Twelve strips 15 mm wide tested using a Schopper-type tensile tester with the jaws initially 9 cm apart.

(c) Tear: Using a Marx-Elmendorf tear tester; normally a group of three were torn at one time through 44 mm in two places (ie total tearing distance is 3 x 2 x 44 = 264 mm), three readings being obtained in this way. Sheets with high tearing strength were torn either in pairs or singly and suitable adjustment was made to the calculation of the tear factor.

(d) Burst: Eighteen tests using a Frank Schopper-Dalen type pneumatic burst tester.

(e) Fold: 15 mm strips folded through 312° and the number of double folds recorded before the strip broke under a load of 7.85 N.

(f) Air porosity: Four sheets tested using a closed top Gurley densometer with a 57 g inner cylinder. The time for 100 cm^3 of air to pass through 6.45 cm^2 was measured by the automatic timing attachment.

(g) Basis weight and moisture content: Determined by weighing six rectangles of 250 cm^2 total area after standard conditioning and after drying to constant weight at 105 ± 3° C.

Results are reported as follows, where possible, independent of basis weight, but otherwise referring to an oven dry basis weight of approximately 60 g/m^2.

Basis weight	Grams per square metre, oven-dry (W)
Thickness	Thickness of a single sheet, in microns
Bulk*	$\frac{\text{Thickness}}{W}$
Burst factor*	$\frac{\text{Average burst in g/cm}^2}{W}$
Tear factor*	$\frac{\text{Tearing force for a single sheet in g} \times 100}{W}$
Breaking length*	$\frac{\text{Average tensile strength in kg} \times 66\,700}{W}$

The result is expressed in metres.
* results which are independent of basis weight.

The ease with which water parts from the pulp was determined by two methods. The first, the drainage time, determined on the standard sheet machine, is the time in seconds for water at 20°C to flow from a pulp suspension through the wire from a height 350 mm above the wire until the formed sheet is no longer immersed. The procedure used was that described in the 'Second Report of the

Pulp Evaluation Committee and is similar to that given in TAPPI Standard T 221 os–63.

The second, the Canadian Standard freeness, is an empirical measure of the rate in which water will separate from a one litre suspension of 3 g of pulp through a standard perforated plate, in apparatus calibrated by the Pulp and Paper Research Institute of Canada. The method is described by the 'Second Report of the Pulp Evaluation Committee', TAPPI Standard T 227 m–58 and in Canadian Pulp and Paper Association Standard C1'.

6. Bleaching and bleaching pulp evaluation

Bleaching trials were carried out by a four stage method of chlorination, extraction, hypochlorite and chlorine dioxide (CEHD). This is the simplest sequence currently used to obtain a fully bleached sulphate pulp. The quantity of chlorine added, sufficient to give an excess that would not be consumed within the reaction time, was estimated from the Kappa number using data for the relationship between Kappa number and chlorine demand from earlier trials.

The brightness was determined using a Elrepho reflection photometer using a TAPPI filter (with an effective wavelength of 457 nm) and a magnesium oxide standard as 100.

The printing opacity was determined using the same instrument with CIE tristimulus filters Y (green). The reflectance from a single 60 g/m^2 sheet (R_o) over a black background was compared with the reflectance from a pad sufficiently thick to ensure no light was transmitted (R_∞).

Then printing opacity = $\frac{R_o \times 100}{R_\infty}$. This figure is dependent on the basis weight of the sheet.

The scattering (SX) was determined from the relationship between the printing opacity $\frac{(R_o \times 100)}{(R_\infty)}$ and the total reflectance. The specific scattering coefficients, which is independent of the basis weight is given by

$$s = \frac{SX \times 10\,000}{W}$$

where W = Basis weight, oven dry in g/m^2, (Giertz, 1950).

The strength characteristics of the bleached pulp were determined as described for unbleached pulps.

References

BRITISH PAPERS MAKERS' ASSOCIATION 1936. *Second report of the Pulp evaluation committee.* London. 168pp.

GIERTZ, H. W. 1950. Opaciteten hos pappermassor. *Svensk Papperstidning 53,* 673–680.

WISE, L. E., MURPHY, M., D'ADDIECO, A. A. 1946. Chlorite holocellulose, its fractionation and bearing on summative wood analysis and studies on the hemicelluloses. *Paper Trade J.,* **122** (2), 35.

TAPPI Standard and suggested methods. New York: The Technical Association of the Pulp and Paper Industry.

Printed in England for Her Majesty's Stationery Office by Hobbs the Printers Ltd, Southampton
(824) Dd113842 1M 7/76 G3313