The Effect of Anthraquinone on the Pulping of Mixed Tropical Hardwoods

PHILLIPS F. H.,* CHIN W. J.,** WILLIAMS M.D.**
AND LOGAN A. F.***

ABSTRACT

As an extension of a general assessment of pulpwood quality of tropical hardwoods from the native forests in Sarawak, Malaysia and Papua New Guinea, attention has been given to soda, kraft and neutral sulphite semichemical (NSSC) processes carried out with the addition of anthraquinone (AQ) to the pulping liquor. Mixed light hardwood (MLH) chips and mixed dipterocarp forest (MDF) residues from Sarawak and Papua New Guinea mixed hardwood chips were used in the investigation and both unbleached and bleached pulps were prepared and evaluated.

Unbleached soda-AQ and NSSC-AQ pulps can be produced from the tropical hardwood chips and in the case of AQ addition to soda and kraft liquors, the alkali concentration required for cooking to a given Kappa number was reduced. Yield and strength properties of soda-AQ pulps were higher than those of soda pulps from the same samples but strengths were not comparable with those of kraft and kraft-AQ pulps. There was no appreciable difference between the strength properties of kraft and kraft-AQ pulps.

There was little, if any, advantage obtained by adding AQ to the liquor during NSSC pulping of these tropical hardwoods.

Both soda-AQ and kraft-AQ pulps from the MLH chips were bleached satisfactorily to acceptable brightness levels with little effect on strength properties.

INTRODUCTION

Extensive studies have been carried out on the pulping and papermaking properties of hardwood resources available in native forests in Papua New Guinea and in Sarawak, Malaysia. The research work has been carried out by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in conjunction with the Papua New Guinea Department of Forests, the Sarwak Forest Department and the Sarawak Timber Industry Development Corporation (11). In the evaluation of the available pulpwood supplies, conventional pulping processes were used and the assessment of pulpwood quality was based on the unbleached and bleached kraft and unbleached neutral sulphite semichemical pulp properties. This was considered desirable in view of the importance of such processes worldwide and the fact that any possibilities for commercial development would probably be based on well established procedures.

Once the general assessment of the pulpwood quality of the resources in these tropical hardwood forests had been completed, studies on other pulpwood processes were carried out. In particular, processes which were more environmentally acceptable and those which could produce higher yields of pulp were of highest p iority. For this reason, attention was given to soda, kraft and neutral sulphite semichemical (NSCC) processes carried out with the addition of anthraquinone (AQ) to the pulping liquor.

The discovery that small additions of certain chemical compounds are capable of greatly accelerating some pulping reactions has brought a new approach to

*Formerly CSIRO, Division of Chemical and Wood Technofogy, now Paper Resources International, 36 Rennison Street, Mordialloc, Vic., 3195, Australia.

**CSIRO, Division of Forestry and Forest Products, Private Bag 10, Clayton, Vic., 3168, Australia.

***Formerly CSIRO, Division of Chemical and Wood Technology. new Frapack Engineering Pty. Ltd., 10 Molan Street, Ringwood, Vic., S3134, Australia.

wood pulping. Pulping with additions of AQ has recently received great attention worldwide and is now a normal procedure in many commercial operations. Several advantages have been reported and these have been summarised by Nelson([12]) and covered in reports by others ([13 17]). The addition of small amounts of AQ in the soda pulping liquor used for pulping *Pinus radiata* produced a pulp only a little inferior to that of the normally stronger kraft pulp. In the case of hardwood pulps, e.g. those from eucalypt pulpwood, the differences between soda-AQ and kraft pulps are less significant. The addition of AQ to most kraft liquors produces an appreciable increase in pulp yield usually with little, if any, effect on pulp strength. Unfortunately, the cost of the AQ needed may balance the saving in wood cost, but where wood costs are high or where plant limitations cause production problems the kraft-AQ process may give economic benefits.

The effect of AQ in neutral sulphite pulping is very limited with temperatezone hardwoods. An increase in pulping rate is obtained with high quality, low density wood but older, denser eucalypts are essentially unaffected. On the other hand *Pinus radiata* gives a dramatic response to AQ with a very marked increase in pulping rate([12]) ([18]) ([19]).

Except for seme work in India([20]) and Australia([21]), most of the published work on AQ pulping has been done on softwoods or temperate-zone hardwoods. Because of the availability of the vast tropical hardwood resources in Papua New Guinea (PNG) and Malaysia, and in view of the advantages claimed by many authors on the use of the AQ, it was considered important to determine whether benefits can be realised with the use of AQ on these mixed tropical hardwoods.

PULPWOOD SAMPLES

Woodchips produced from mixed light hardwood (MLH) forest and mill residues at the mill at Rejang, Sarawak, Malaysia are exported for pulping and papermaking. In recent years the major supply has been MLH cordwood from Sarawak's peat swamp forests and the pulping and papermaking quality of this material was the subject of a recent publication([9]). Fresh chip samples as described in that study were used for the majority of the AQ pulping work described herein and the species composition of each of the samples can be obtained from the earlier paper. Sampling of freshly prepared chips was carried out daily and 0.2 kg batches were collected at hourly intervals from the conveyor system from the chipper over the 16 hour operating period each day. Composite fr sh chip mixtures were prepared to represent material produced between shipments and the composite sample used for the majority of the work in the present study contained about 400 separate samples collected over a period of 34 days.

The other source of woodchips from Malaysia used in this AQ pulping study was a mixture prepared to represent mixed dipterocarp forest (MDF) resources available in Sarawak from clear-felling residues. These residues excluded large trees of commercial species. A total of over 400 species were represented and these are described elsewhere[11].

In Papua New Guinea, woodchips are produced for export at the JANT Pty. Ltd. mill at Madang from the mixed tropical hardwoods found in the Gagol timber area. The pulpwood is obtained from clear felling operations, with high quality cabinet woods and large trees of select sawmilling species excluded[4], and is used mainly for kraft pulping in Japan for liner-board production. The PNG mixed hardwood sample used for the AQ pulping tests was collected during loading of the vessel over a period of about 3 days and contained a mixture of fresh and stored chips.

EXPERIMENTAL

Pulp Preparation

Preliminary soda and soda-AQ pulping tests were carried out in 2L capacity stainless steel reaction vessels, heated in a temperature controlled air bath, to determine AQ additions for subsequent studies.

For the majority of the work, pulps were prepared on a larger scale in a 20L capacity electrically heated stainless steel rotary digester from 1400g (o.d.) samples For soda, soda-AQ, kraft and kraft-AQ, the following standard pulping conditions were used : liquor : wood ratio 3.5 : 1, cooking temperature 170°C, time to temperature 1.25 h, time at temperature 2 h, blow down time 0.3 h. The active alkali and the $NaOH$ charges for kraft– and soda–type cooks respectively are shown in the tables. For kraft-type cooks the sulphidity was 25 percent in all cases and the addition of AQ to soda–AQ and the kraft–AQ and the kraft–AQ

cooks was constant at 0.05 percent. Cooked chips were disintegrated to produce fibre separation and washed thoroughly until the filtrate was colourless. The pulps were screened on a Packer screen with 0.2 mm slots in the screen plate.

NSSC and NSSC–AQ pulps were prepared in the same 20L digester using 15 percent Na_2SO_3 and 3.5 percent Na_2CO_3 (based on o.d chips at 170°C. Time to temperature was 1.5 h and at temperature 2 h. Liquor : wood ratio was 3.5:1 and in NSSC–AQ cooks the AQ addition was 0 1 percent. After cooking, defibration of the chips was carried out in a 203 mm diameter laboratory Bauer refiner operating at 3000 rev/min. Rubbing plates were used at a clearance of 2 5 mm (1 pass), 0.4 mm (1 pass), 0.1 mm (1 pass) and 0.05 mm (2 passes). After defibration the NSSC–type pulps were processed in a similar manner to the kraft– and soda–type pulps.

Pulp Bleaching

Bleaching was carried out on certain soda– and kraft–type pulps, using a standard CEHD (Chlorination — alkali extraction — hypochlorite — chlorine dioxide) or CEHDED sequence according to procedures described by Phillips *et al*[22] but conditions for each stage are shown in the tables foilowing. Pulp brightness was measured with an Elrepho reflectometer; test pads were prepaped from bleached pulps as outlined in SCAN method C11:62.

Pulp and Paper Evaluation :

Kappa numbers of screened pulps were determined according to Appita standard method P20lm-77.

Pulps were beaten in a PFI mill according to Appita standard method P209 rp—82 Handsheets were prepared and tested according to Appita methods P203s-80 and P208m-75 respectively. The atmosphere of the test room was controlled at 65 percent relative humidity and 20°C. Concora crush resistance was detemined for NSSC pulp handsheets (120 g/m^2) by Appita standard P434 ts-75 Paper brightness and opacity of bleached pulps was measured on handsheets. Vessel picking tendency was determined by means of an IGT Printability Tester according to the procedure described by Colley[23]; a commercial machine-glazed litho paper was used as a reference. Surface roughness of handsheets was measured on the glazed side with a Parker Print-Surf instrument set at 980kPa clamping pressure to correspond with off-set printing conditions.

RESULTS AND DISCUSSION

Soda-AQ and Kraft-AQ Pulps Unbleached pulps

In the preliminary experiments to study the response of tropical hardwood mixtures to soda-AQ pulping, varying amounts of AQ were added. The chip sample used for these investigations was a fresh MLH chip mixture similar to but not identical to that used in later tests on MLH chips. The results (see Table 1) show that small amounts of AQ were sufficient to increase the delignification rate. An addition of 0 05 percent AQ, based on o.d. wood, to a soda cook lowered the Kappa number by as much as 44 percent.

Comparison with a kraft pulp at a similar Kappa number (c 40) shows that the sceened pulp yields of the soda-AQ pulps were similar to the kraft pulp, and there was a lower amount of screen rejects. (Reference Table 1)

The papermaking properties of the soda-AQ pulps are table 2. Results indicated that there was no appreciable differences among the three soda-AQ pulps produced with varying amounts of anthraquinone. Therefore, to achieve economies in the use of AQ, it was decided that in the subsequent tests of soda-AQ and kraft-AQ pulping on the various Sarawak woodchip samples, a 0.05 percent addition of the chemical would be used (based on o.d. wood).

These preliminary experiments should be used as a guide only but they do indicate that the soda-AQ process can probably be used with mixed tropical hardwoods and could be a suitable replacement for the kraft process in some circumstances. (Reference Table-2)

Fresh MLH chips and MDF clearing residues from Sarawak and the PNG mixed hardwoods used in subsequent tests for the production of unbleaced soda and kraft pulps with AQ as an additive were pulped in a 20 litre rotary digester. The larger woodchip charge improves the represntation of the various species in the chip mixtures. The aim was to pulp each chip mixture under the same cooking conditions except for variation of the alkali concentration required to produce pulps at Kappa numbers c. 20 and 45. At the lower Kappa number pulp properties can be used to assess the quality

TABLE—1 PROPERTIES OF UNBLEACHED SODA, SODA-AQ AND KRAFT PULPS

Prelimina.y Cooks with mixed light hardwood chips

Type of cook	Cook No.	Active* alkali (as Na_2O) %	Anthraquinone* (%)	Yield + (%)			Kappa No. (screened pulp)
				Unscreened	Screened	Screen rejects	
Soda	1	13	0	51.0	46.5	4.5	77.4
Soda-AQ	2	13	0 05	48 9	47.0	1.4	43.3
Soda-AQ	3	13	0.10	50.0	48 5	1.1	40.9
Soda-AQ	4	13	0.50	49 2	47.1	1.5	34 9
Kraft	5	13	—	49.1	46.8	2.0	41.1

* Based on oven dried wood

\+ Oven dried pulp as percentage of oven dried wood.

TABLE—2 PAPERMAKING PROPERTIES OF UNBLEACHED SODA-AQ PULPS

(Preliminary cooks in small scale vessels)

(For description of samples and pulping conditions, see Table 1)

Cook No.	Kappa No. (screened pulp)	Beating (PFI) (rev)	Freeness (CSF)	Handsheet properties (o.d. grammage 60 g/m²)					
				Bulk (cm^3/g)	Tear index ($mN\ m^2/g$)	Breaking length (km)	Stretch %	Burst index ($kPa.m^2/g$)	Folding endurance
2	43.3	0	630	2.15	5.4	2 3	1.5	1.1	2
		2000	479	1.85	9.7	3.7	3 1	3.1	37
		4000	315	1.73	9.9	6.8	3.3	4 4	198
		8000	108	1.59	10.2	8 4	4.0	5.9	891
3	40.9	0	613	2.03	5.4	3.0	2.1	1.3	2
		2000	433	1.88	9.9	5.4	2 7	3.3	39
		4000	277	1 68	10.8	7.3	3.5	5.0	159
		8000	93	1.55	10.2	8.3	4.3	6.1	896
4	34 9	0	607	2.17	6.0	3.1	2.0	1.3	3
		2000	444	1.77	10.6	6.1	3 1	3 9	62
		4000	260	1.70	10.8	7.2	3 3	5 3	262
		8000	79	1.56	10.5	8.2	3 8	6.8	1577

of pulps for bleaching as well as for unbleached products. At Kappa number c 45 properties indicate the suitability for a wider range of paperboard products such as liner board.

The pulping results in Table 3 indicate that, for the production of unbleached soda pulps from both fresh MLH chips and MDF residues at a similar Kappa number (c.22), the addition of small amounts of AQ (0 05 percent based on oven dried wood) to the soda cooking liquor allowed a reduction in the sodium hydroxide concentration of 4 percent (as Na_20). There was also an increase in screened yield of unbleached pulp of c. 3-4 percent (based on oven dried wood). On cooking to a higher Kappa number (c. 42-43), the alkali concentration required was 3 percent lower with AQ addition than normal soda kooking liquor. Unscreened yield of these higher Kappa number pulps was appreciably higher (2 3 percent) but the screened yields of the soda and soda–AQ pulps were similar because of the large amount of screen rejects in the latter pulp. The amount of screen rejects was not decreased by the use of AQ. In fact, the addition of AQ to the soda cook caused an increase in screen rejects of 0 2 and 2.8 percent when pulped to Kappa numbers c. 22 and 43 respectively. This was contrary to the results obtained in preliminary experiments and indicates that the benefits of AQ pulping may be species dependent and certain chip mixture may not respond well to AQ pulping.

The addition of AQ to the soda cooking liquor used in pulping PNG mixed hardwoods reduced the sodium hydroxide concentration by 6 percent (as Na_2O). There was also an increase of c. 4 percent in the screened yield of pulp produced at Kappa number 23. (Reference Table 3)

In the case of the kraft–AQ cooks, the use of AQ resulted in a reduction of up to 1 percent in the active alkali concentration of the kraft liquor required for pulping MLH chips, MDF residues and PNG mixed hardwoods to Kappa number c. 20. There was no appreciable difference in the screened yields or the amounts of screen rejects obtained with the use of AQ (See Table 3).

The papermaking properties of the unbleached soda, soda–AQ, kraft and kraft–AQ pulps are shown in Table 4 and some of the results are illustrated in Figures 1 and 2. The properties of kraft–AQ pulp at Kappa numbers c. 20 and 45 were generally similar to kraft pulps from the same chip samples. However, the properties of soda–AQ pulps at both levels of Kappa number (i.e. c. 20 and 45) were higher than those of soda pulps from the same samples compared at similar freeness levels or after similar beating. Overall, the stregth properties (e.g. tear index, burst index, breaking length) of the pulps at Kappa numbers c. 20 and 45 increased in the following order of pulp type : soda → soda–AQ → kraft → kraft–AQ (Reference Table 4 and fig. 182)

TABLE 3
PROPERTIES OF UNBLEACHED SODA, SODA.AQ, KRAFT-AQ PULPS

Wood samples : Mixed light hardwood (MLH) chips and mixed dipterocarp forest (MDF) clearing residues from Sarawak, Malaysia and Papua New Guinea (PNG) mixed hardwoods

Type of pulp	Active alkali+ (as Na_2O) (Z)	Anthraquinone* (Z)	Yield+ (Z)			Kappa No. (screened pulps)
			Unscreened	Screened	Screen rejects	
Mixed light hardwoods						
Soda	21.0	—	43.7	42.6	0.1	22.2
Sod-AQ	17.0	0.05	47.2	46.5	0.3	22.4
Kraft°	16.0	—	45.5	44.9	0.4	20.0
Kraft-AQ	15.0	0.05	46.1	45.7	0.5	19.8
Soda	15.0	—	49.4	48.2	1.0	42.3
Soda-AQ	12.0	0.05	51.7	47.9	3.8	43.2
Kraft°	11.5	—	50.9	47.5	3.3	38.6
Kraft-AQ	11.0	0 05	53.9	47.9	5.3	49.6
MDF residues						
Soda	22.5	—	42.2	41.5	0	22 6
Soda-AQ	18.5	0.05	44.9	44.8	0	22 0
Kraft*	17·5	—	46.3	45 7	0.1	20.9
Kraft-AQ	17.0	0.05	45.8	45.6	0.1	19.0
PNG mixed hardwoods						
Soda	22.0	—	42.5	42.2	0.1	23.0
Soda-AQ	16.0	0.05	46.6	46.3	0.3	23.1
Kraft	15.0	—	47 4	47.0	0.1	22.2
Kraft-AQ	14.5	0.05	47.3	46.7	0.3	22.6

* Based on oven dried wood
\+ Oven dried pulp as percentage of oven dried wood
° Data obtained form Ref (9)
† Data obtained form Ref. (11).

TABLE—4 PAPERMAKING PROPERTIES OF UNBLEACHED SODA, SODA-AQ, KRAFT AND KRAFT-AQ PULPS

(For description of samples and pulping conditions see Table 3)

Type of pulp	Kappa No.	Beating (PFI) (rev)	Freeness (CSF)	Handsheet properties (o.d. grammage 60g/m²)					
				Bulk (cm^3/g)	Tear index ($mN.m^3/g$)	Breaking length (km)	Stretch (%)	Burst index ($kPa.m^2/g$)	Folding endurance
Mixed light hardwoods									
Soda	22.2	0	670	2.21	3.7	1.7	1.6	0.7	1
		2000	514	1.86	5 7	3.6	2.8	1.8	5
		4000	297	1.67	6.0	4.5	2.9	2.6	10
		8000	84	1.52	5 5	5.3	3.3	3.2	27
Soda-AQ	22.4	0	596	2.02	6.3	2.0	2.2	1.1	2
		2000	420	1.68	6 9	4.3	3.6	2.6	10
		4000	230	1.57	6.9	5.3	3.9	3.5	20
		6000	102	1.50	6.4	5.9	4.2	3.9	27
Kraft°	20.0	0	673	2.13	4.9	2.3	2.3	1.0	3
		2000	531	1.73	10.2	5.7	3.8	3.5	35
		4000	353	1.61	10.3	7.3	4.4	5.0	221
		8000	124	1.50	9.8	8.1	4.7	6.2	658
Kraft-AQ	19.8	0	648	2.10	5.0	2.0	2.1	1.0	2
		2000	464	1.71	9.0	5.1	4.2	3.3	40
		4000	287	1.59	9.6	6.9	4.6	4.7	157
		8000	97	1.49	9.4	8.2	5.0	6.0	730
Soda	42.3	0	622	2.31	4.4	2.0	1.7	0.9	2
		2000	482	1.90	8.7	4 6	2.8	2.6	11
		4000	325	1.77	8.6	5.7	3.4	3.4	26
		8000	109	1.64	8.5	6.9	3.9	4.5	94
Soda.AQ	43.2	0	636	2.27	5.3	2.2	2.1	1.0	2
		2000	449	1.86	9.3	5.0	3 2	3.0	19
		4000	295	1.72	10.1	6.6	3 8	4.4	69
		8000	95	1.61	9.9	7.8	4.6	5.8	612
Kraft°	38.6	0	650	2.04	6.3	2.7	1.9	1.3	3
		2000	475	1.76	11 0	6.1	3.6	3 6	69
		4000	300	1.64	11.0	7.7	4.5	5.2	299
		8000	101	1.53	10.4	9.3	5 0	6.3	1420
Kraft-AQ	49.6	0	618	2.12	6 6	2.8	2.4	1.4	3
		2000	454	1.80	10.8	6.1	4.0	3.8	43
		4000	277	1.67	11 2	7 4	4.8	5.4	413
		6000	161	1 60	11.1	8.3	5.4	6 1	668
MDF Residues									
Soda	22.6	0	607	2 21	5.0	2.1	2.1	1.0	2
		2000	473	1.92	7.0	3.5	2 6	1.9	5
		4000	290	1.81	6.5	4.2	3.1	2 4	8
		6000	150	1.72	6.0	4.6	3.5	2.6	11

Type of pulp	Kappa No.	Beating (PFI) (rev)	Freeness (CSF)	Handsheet properties (o d. grammage 60g/m)²					
				Bulk	Tear index	Breaking length	Stretch	Burst index	Folding endu-rance
				(cm^3/g)	($mN\ m^2/g$)	(km)	(%)	$kPa.m^2/g$)	
Soda-A-Q	22.0	0	624	2.20	4.9	1.9	2.1	1.0	2
		2000	489	1.90	8.4	4.1	3.1	2.3	10
		4000	318	1.78	8.4	5.3	3 7	3.1	21
		8000	99	1.63	7.8	6.1	4.0	3 8	38
Kraft°	20.9	0	653	2.31	5.5	2.0	2.0	0.6	2
		2000	517	1.91	9.6	4.8	3.1	2 6	13
		4000	390	1.78	9.6	6.0	3.6	3 3	37
		8000	169	1.69	10.5	6.9	4 2	4 3	123
Kraft-AQ	19.0	0	621	2.16	5.4	2.2	2.1	1.1	1
		2000	494	1.85	10.1	4.9	3.3	2.8	19
		4000	351	1.74	10.4	6.1	3.9	4.0	49
		8000	150	1.62	13.3	7.7	4.4	5.1	254
PNG mixed hardwoods									
Soda		00	617	2.09	6.2	2.3	2 3	1 2	3
	23.0	2000	460	1.75	7.1	4.6	3 2	2.5	12
		4000	267	1.63	6.9	5.4	3.7	3.1	24
		6000	152	1.53	6.4	5.9	4.1	3.6	29
Soda-AQ		00	596	2 05	6.3	2.6	2.2	1.3	3
	23.1	2000	437	1 73	8.6	5.4	3 3	3.4	24
		4000	282	1.61	8 3	6.7	4.1	4 6	72
		6000	170	1.50	7.5	7.4	4.3	4.9	136
Kraft		00	613	2.00	7.0	2 6	2.8	1.1	3
	22.2	2000	418	1.69	9.3	5.6	3.8	3.6	67
		4000	260	1.59	10,1	7.2	4.4	4.8	216
		8000	85	1.41	9.7	8 7	4.8	5.7	1353
Kraft-AQ		00	608	1.97	7.3	2.7	2.1	1 5	4
	22 6	2000	436	1.63	9.9	6.5	3.9	4.3	85
		4000	283	1.55	9.9	7.6	4 5	6.1	301
		6000	162	1.47	9.4	9.0	5 3	6,9	726

○ Data obtained from Ref (9)

ϕ Data obtained from Ref (11).

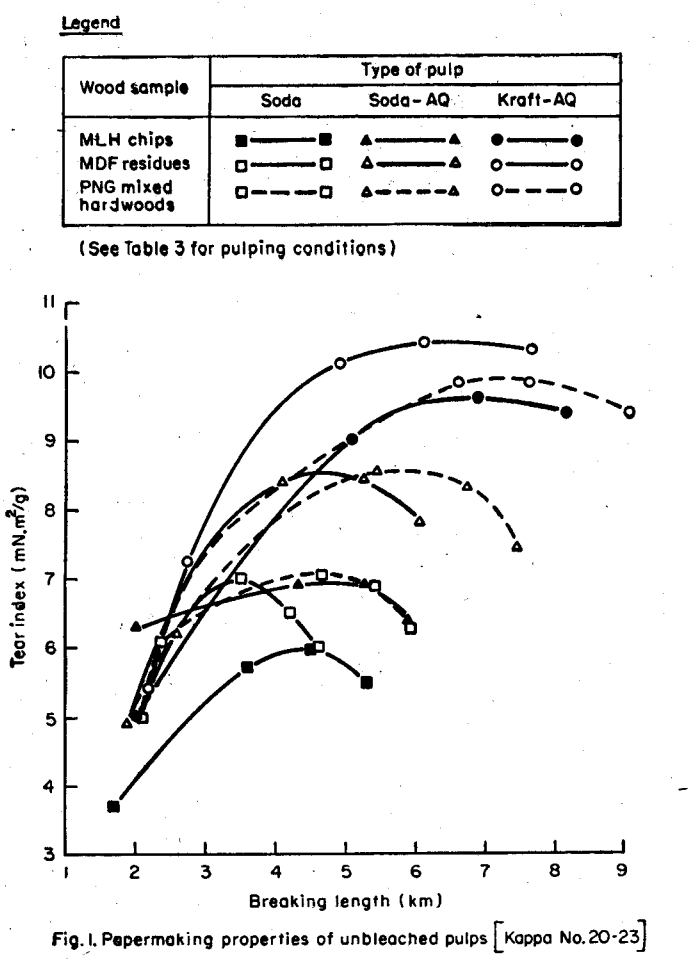

Fig. 1. Papermaking properties of unbleached pulps [Kappa No. 20-23]

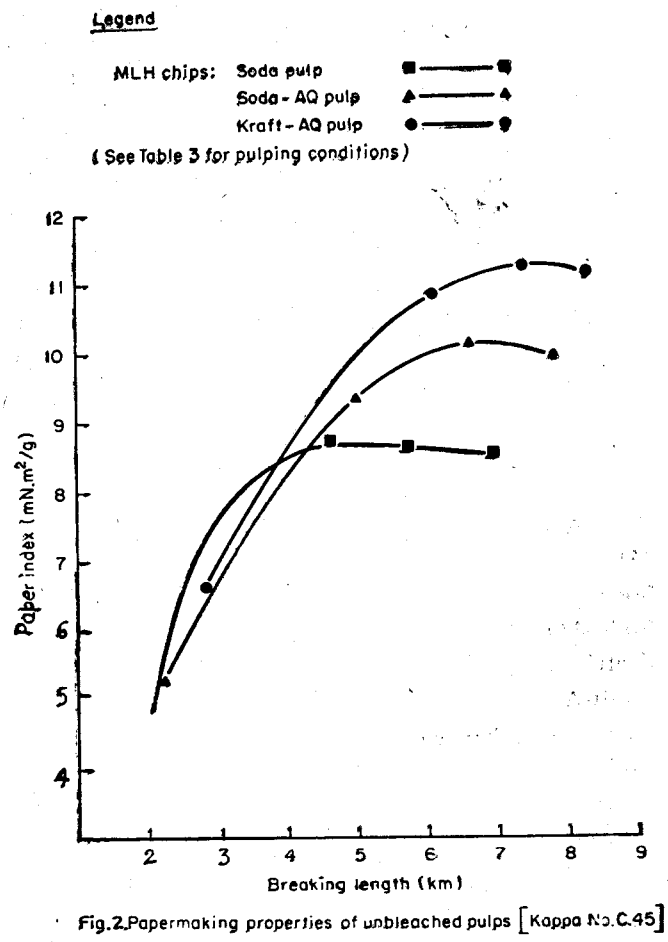

Fig. 2. Papermaking properties of unbleached pulps [Kappa No. C-45]

For ease of comparison, the papermaking properties of the unbleached pulps at a freeness of 250 CSF and the tear index at 7 km breaking length have been compiled in Table 5. At 250 CSF, the soda–AQ pulp from all three wood samples had substantially higher tear index, breaking length and burst index than soda pulp from the same sample at a similar Kappa number (c. 22–23 and 43). Tear index at a constant breaking length of 7 km also increased considerably on AQ addition. Irrespective of these increases, the strength values of the soda–AQ pulps were lower than those of kraft pulps. There was no significant differences in the strength properties of kraft and kraft–AQ pulps at the two levels of Kappa number (c. 20 and 45) (Reference Table 5)

On the basis of the above results, it is evident that both soda–AQ and kraft–AQ pulps can be produced from the tropical hardwood chips from Sarawak, Malaysia and Papua New Guinea. However, the unbleached soda–AQ pulps from these tropical hardwood mixtures would have some limitations when considered for utilization as a replacement for unbleached kraft pulps in end products in which a somewhat lower level of strength is acceptable, the soda–AQ pulps should be satisfactory for use, especially as there is an appreciable yield advantage compared with soda pulp.

Bleached Pulps

To study the effect of AQ pulping on bleaching characteristics, beatability and strength properties, the soda-AQ and kraft-AQ pulps of Kappa number c. 20 from two samples of MLH chips were bleached by a standard CEHD bleaching sequence The soda-AQ pulp was also subjected to a CEHDED bleach sequence. One of the MLH chip samples, as indicated in the tables, was used for the unbleached pulp results quoted earlier, the other was similar but collected from the

TABLE 5

COMPARISON OF PAPERMAKING PROPERTIES OF UNBLEACHED SODA, SODA-AQ, KRAFT AND KARFT-AQ PULPS

Type of pulp	Kappa No.	At 7.0km breaking length Tear index ($mN.m^3/g$)	At 250 CSF Tear index ($mN\ m^1/g$)	At 250 CSF Breaking length (km)	Burst index ($kPa\ m^2/g$)
Mixed light hardwoods					
Soda	22.2	<4.0	6.0	4.7	2.8
Soda–AQ	22,4	5.3	6.9	5.3	3 4
Kraft°	20.0	10.3	10.1	7.7	5.6
Kraft–AQ	19.8	9.6	9.6	7.2	5.0
Soda	42 3	8.5	8,6	6 2	3.8
Soda-AQ	43.2	10.1	10.1	6.9	4.7
Kraft°	38.6	11.1	10.9	8.1	5.5
Kraft-AQ	49 6	11.1	11.2	7.6	5.6
MDF residues					
Soda	22.6	<4.0	6.4	4.3	2.5
Soda-AQ	22 0	6.2	8.2	5.6	3.3
Kraft*	20.9	10.5	10.4	6.7	4.0
Kraft-AQ	19.0	10.4	10.4	6.0	4 6
PNG mixed hardwoods					
Soda	23.0	<4.0	6.9	5.6	3 3
Soda-AQ	23.1	8.2	8.2	6.9	4 7
Kraft	22.2	10.0	10.2	7.4	5.1
Kraft-AQ	22.6	9.9	9.8	8.5	6 4

° Data obtained from Ref (9)
* Data obtained from Ref (11).

woodchip mill at a different time. The resulting pulp and papermaking properties are shown inoTables 6 and 7 and Figure 3. (Reference Table 6 & 7 and Figure 3)

A bleached kraft-AQ pulp was not prepared from the same MLH sample as used for the bleached soda-AQ and bleached kraft pulps. However, the results obtained on the samples A and B, when pulped by either the soda-AQ or kraft process, were very similar, as shown in Table 6, and it can therefore be assumed that CEHD bleached kraft-AQ pulp from sample A would be similar to that obtained from sample B. Direct comparison of the bleached kraft-AQ pulp properties given in Table 6 with bleached soda-AQ or bleached kraft pulps from sample A is possible.

The AQ pulps bleached readily and the chlorine requirements and bleached pulp yields compared favourably with these properties of the bleached kraft pulps. The CEHD bleached kraft-AQ pulp had a satisfactory brightness of 84.4, whereas ihe CEHD bleached soda-AQ pulps had a lower brightness (c 82) However, by using a six stage CEHDED sequence, the soda-AQ pulp was bleached to a high brightness level of 88. Yield, on an original wood basis, was only slightly lowered when bleaching with the extra stage in the CEHDED sequence.

Comparison of results in the Tables 4 and 7 shows that the addition of AQ does not affect the beatability or the properties of bleached pulps. Strength properties at 250 CSF and tear index at 7 km breaking length are given in Table 8 to assist the comparison. The results in Tables 5 and 8 show that there was no appreciable change in the level of strength properties of the AQ pulps after bleaching. (Reference Table 8 .

Printability tests on bleached pulps

The vessel picking tendency and surface roughness of bleached handsheets made from MLH woodchips

TABLE 6

PROPERTIES OF BLEACHED PULPS FROM MIXED LIGHT HARDWOODS

Type of pulp	Sample	Bleaching sequence	Kappa No. (screened, unbleached pulp)	Chlorine demand* (%)	Total Cl_2* consumed in C & H stages (%)	Yield+ (Z) UB	Yield+ (Z) OWB	Pulp brightness (Elrepho)
Soda-AQ	A	CEHD	22.4	4.7	5.8	89.5	41.6	81,8
	B	CEHD	22,7	4.3	5.7	88.8	40.1	82.0
Soda-AQ	A	CEHDED	22 4	4.7	5,9	87 4	40.6	88.0
Kraft°	A	CEHD	20.0	4 3	5.4	92 1	41.4	85,9
	B	CEHD	19.6	3.9	5.0	89.0	41.8	84.6
Kraft-AQ	B	CEHD	21.1	4.0	5,2	86.5	39.9	84 4

+ Based on oven dried unbleached pulp

* Oven dried pulp as a percen.age of :

UB, screened unbleached pulp (oven dried)

OWB, original wood (oven dried)

° Data obtained from Ref (9)

Note : Sample A is identical with that used for pulping results quoted in Table 3.

TABLE 7

PAPERMAKING PROPERTIES OF BLEACHED PULPS FROM MIXED LIGHT HARDWOODS

(For bleaching properties asee Table 6)

Type of pulp	Kappa No. (unbleached pulp)	Bleaching sequence	Beating (PFI) (rev.)	Freeness (CSF)	Handsheet properties (o.d. grammage 60g/m²) Bulk (cm^3/g)	Tear index ($mN.m^2/g$)	Breaking length (km)	Stretch (%)	Burst index ($kPa.m^2/g$)	Folding endurance	Brightness (Elrepho)	Opacity (%)
Soda-AQ	22.4	CEHD	0	594	2.07	5.1	2.1	2.4	0.9	2	80 7	74.0
			2000	420	1.71	7.4	4.4	3.7	2,5	13	79.6	71 5
			4000	220	1.58	7.5	5.4	3.8	3.5	28	79.3	70.0
			6000	116	1.51	6.9	5.7	3.7	4.2	46	79.0	69.4
Soda-AQ	22.4	CEHDED	0	596	2 02	6.3	2.0	2.2	1.1	2	86.9	71.9
			2000	420	1.68	6 9	4.3	3.6	2.6	10	86.1	69.6
			4000	230	1.57	6.9	5.3	3.9	3 5	20	85 9	68.7
			6000	102	1 50	6 4	5.9	4.2	3.9	27	85.8	68.1
Kraft°	20.0	CEHD	0	612	2 04	6 1	2.1	2.0	1.1	2	84.2	73.3
			2000	472	1 69	9.8	5.1	3.8	3.1	26	82.2	71 2
			4000	297	1.55	9.4	6.5	4.3	4.4	60	82.5	69.7
			8000	100	1.44	9.0	7.2	4.9	5.6	182	81.9	67.7
Kraft-AQ	21.1	CEHD	0	571	1.94	5.7	2.2	2.5	1.1	2	82.6	72 5
			2000	440	1.71	9.1	4.9	4 3	3.0	23	81.5	69.7
			4000	274	1.58	9.6	6.3	4.8	4.3	74	81.0	67.6
			6000	148	1.54	9.5	7.3	4.9	5.1	125	80.7	67.1

° Data obtained from Ref (9)

TABLE 8

COMPARISON OF PAPERMAKING PROPERTIES OF BLEACHED SODA-AQ, KRAFT AND KRAFT-AQ PULPS FROM MIXED LIGHT HARDWOOD

Type of pulp	Bleaching Sequence	At 7.0 breaking length Tear index (mN.m²/g)	At 250 Csf Tear index (mN.m²/g)	Breaking length (km)	Burst index (kPa m²/g)
Soda-AQ	CEHD	6.2	7.5	5 3	3.5
Soda-AQ	CEHDED	6.3*	7.0	5.2	3.4
Kraft	CHED	9.0	9.3	6.7	4.7
Kraft.AQ	CEHD	9.6	9 6	6.5	4 5

* Interpolated at 5.0 km breaking length

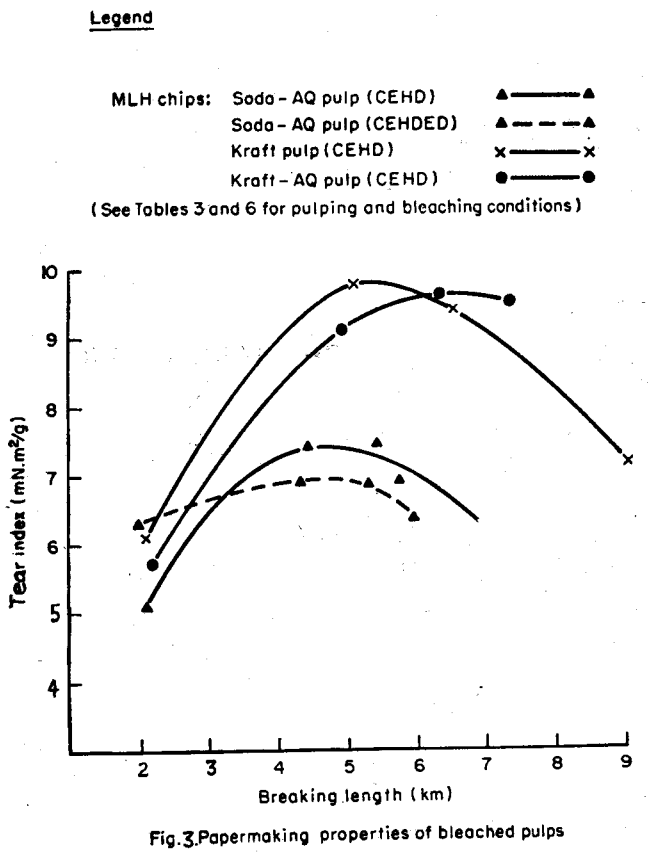

Fig.3.Papermaking properties of bleached pulps

by the soda-AQ, kraft and kraft-AQ processes are given Table 9. As expected, beating markedly reduced the vessel picking tendency of the various pulps and generally reduced the surface roughness. No major differences existed in the vessel picking tendency of the different types of pulps although the Soda-AQ pulp handsheets gave slightly higher values than kraft and kraft-AQ pulp sheets when compared at a similar freeness (300 CSF). (Reference Table 9)

NSSC-AQ Pulps

NSSC-AQ pulping of both softwoods and hardwoods, reported by various authors [17] [19], has shown the optimum amount of AQ to be between 0.1 and 0 2 percent, based on oven dried wood. In the experiments on MLH and PNG mixed hardwood chips a 0.1 percent AQ dosage was chosen for the NSSC-AQ cooks.

Comparison of the pulping properties of NSSC and NSSC-AQ pulps from MLH samples shows that addition of 0.1 percent AQ had no significant effect on unscreened pulp yield (Table 10). With AQ addition, the Kappa number decreased compared with NSSC pulps prepared under similar conditions but the screen rejects of the NSSC-AQ pulps, after the normal number of passes through the Bauer refiner, was unusually high (about 5 percent). This amount of screen rejects can, howevar, be further fiberized resulting in an increase in the screened yield With PNG mixed hardwood, the AQ addition had no effect on Kappa number but the yield of screened pulp was increased slightly. (Reference Table 10)

Compared with the NSCC pulps from MLH chips, the NSSC-AQ pulps exhibited slightly higher tearing and bonding strengths at a given freeness, but similar crush resistance (Table 11). There was very little difference in any papermaking properties between NSSC-AQ pulps from PNG mixed hardwoods. Reference Table 11)

CONCLUSIONS

Unbleached soda-AQ Kraft-AQ and NSSC-AQ pulps can be produced from the tropical hardwood chips from native forests in Sarawak, Malaysia and Papua New Guinea.

TABLE 9

SURFACE PROPERTIES OF BLEACHED PULP HANDSHEETS FROM MIXED LIGHT HARDWOODS

Type of pulp	Beating (PFI) (rev)	Freeness (CSF)	Vessel pick No. IGT) (per 2000mm²)	Vessel pick of sample divided by vessel pick of reference	Surface roughness (Parker Print-Surf) (um)
Soda-AQ	0	594	—	—	7 0
(CEHD(	2000	420	66	0.94	5 6
	4000	220	19	0.27	4.8
	6000	116	7	0.10	4.9
Soda-AQ	0	596	—	—	6.9
(CEHDED)	2000	420	60	0.86	5.5
	4000	230	22	0.31	4.8
	6000	102	8	0.11	4.7
Kraft	0	612	—	—	7.1
(CEHD)	2000	472	66	0 94	5.5
	4000	297	19	0 27	4.9
	8000	100	5	0.07	6.1
Kraft-AQ	0	571	—	—	7.2
(CEHD)	2000	440	59	0.84	5.7
	4000	274	15	0 21	5.1
	6000	148	6	0.09	5.2

IGT Tester conditions : speed 1.2 m/s. load 490 N

Parker print-Surf condltions : clamping pressure 980 kPa

TABLE 10

PROPERTIES OF UNBLEACHED NSSC–AQ PULPS

Type of pulp	Sample	pH		Residual So_2 (%)	Yield* (%)			Kappa No. (screened pulp
		Initial	Final		Unscreened	Screened	Screen rejects	
Mixed light hardwoods								
NSSC	A°	1J.5	10 4	2,3	71.7	71.1	0.4	142
	B°	11.5	9.9	2.2	70.2	69.9	0 1	149
NSSC–AQ	A	11.8	10 4	1.7	71.2	63.7	—	133
	B	11.9	10.1	1,3	68 8	63.1	5 1	126
	B+	11.9	10.3	1.3	67.4	66.6	0.1	131
PNG mived hardwoods								
NSSC+		12 0	10.3	—	74.0	71.9	1.5	139
NSSC-AQ‡		12.0	10.2	—	—	74.2	1.1	141

* Oven dried pulp as percenjage of oven dried wood

° Data obtained from Ref (9)

\+ Reject recirculated through reflner for an additional 2 passes at 0.05 mm clearance

‡ Total pulp yield recirculated through reflner for an additional 7 pesses at 0 05 mm clearance.

TABLE 11
PAPERMAKING PROPERTIES OF UNBLEACHED NSSC AND NSSC-AQ PULPS
(For Pulping Conditions See Table 10)

Type of pulp	Kappa No.	Beating (PFI) (rev)	Freeness (CSF)	Handsheet properties (o.d.) grammage 60g/m² Bulk (cm³/g)	Tear index (mN.m²/g)	Breaking length (km)	Stretch (%)	Burst index (kPa.m²/g)	Folding endurance	Crush* resistance (CMT) (N)
Mixed Light hardwoods										
NSSC°	142	0	663	2.53	4.0	2.1	1.5	0.8	1	93
		2000	525	2.30	6.3	3.4	2.0	1.6	5	201
		4000	360	2.15	7.3	4 5	2.3	2.4	11	291
		8000	157	1.91	7.4	6.0	2.9	3 5	52	339
NSSC-AQ	133	0	688	2.46	4.4	2.1	1.8	0.9	2	—
		2000	520	2.22	6 6	3 8	2.4	1.8	7	218
		4000	365	2.01	8.1	5.2	2.9	2.7	20	323
		8000	150	1.87	7.8	6.4	3 3	3.7	74	347
PNG mixed hardwoods										
NSSC	139	00	683	2.67	4.3	1.9	1.6	0.8	2	60
		2000	558	2 27	6.4	3 8	2.3	1.8	4	184
		4000	437	2.07	7.2	4.7	2 6	2.5	12	275
		8000	190	1.81	6.6	6.0	2.9	3.7	39	366
NSSC-AQ	141	00	705	2.68	4 0	1.7	1.4	0.7	1	—
		2000	604	2.21	6.2	3.3	2.1	1.7	4	166
		4000	464	2.03	6.6	4.9	2.8	2.4	10	252
		8000	207	1.81	7.1	6.4	3.2	3.6	45	373

* Data obtained from Ref (9)
Handsheets o. d. grammage 120g/m²

The addition of 0.05 percent AQ to soda and kraft liquors reduced the alkali required for cooking to a given Kappa number. The level of strength properties of the unbleached soda-AQ pulps from these tropical hardwoods was higher than those of soda, but lower than the kraft and kraft-AQ pulps. The soda-AQ pulps, while environmentally more acceptable than kraft-type pulps, would have some limitations when considered for utilization in unbleached papers requiring high bonding and tearing strengths. In view of the appreciable yield advantage compared with soda pulp, these soda-AQ pulps could be satisfactory for use in many unbleached products in which a somewhat lower level of strength is acceptable.

Unbleached kraft and kraft-AQ pulps from MDF residues and PNG mixed hardwoods at Kappa number c. 20 and from MLH chips at both c. 20 and c. 45 Kappa number possessed comparable levels of strength. Overall, the strength properties (e.g. tear index, burst index and breaking length) of the pulps at the two levels of Kappa number increased in the following order of pulp type: soda → soda-AQ → kraft/kraft-AQ.

The addition of 0.1 percent AQ to the NSSC cooking liquor reduced the Kappa number of unbleached pulps from MLH chips slightly but had no significant effect on unscreened pulp yield. With PNG mixed hardwoods the AQ addition resulted in a small increase in screened pulp yield at a constant Kappa number. However, there was little, if any, advantage in papermaking properties obtained by the addition of AQ to NSSC pulping liquor.

Both soda-AQ and kraft-AQ pulps from MLH chips can be bleached satisfactorily to aeceptable brightness levels with little reduction in strength properties comparen with the unbleached pulps.

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