Studies on the Kraft Pulping of Mixed Tropical Hardwoods in the Presence of Anthraquinone

NAYAK, R.G.,* HANDIGOL, S.G.,** MESHRAMAKAR, P.M.,***
DEB, U.K.,**** JASPAL, N.S.*****

SUMMARY

Alkaline pulping with the addition of anthraquinone (AQ) has captured world attention. Several advantages have been claimed, viz., increase in yield, reduction in H-factor and lowering of sulphidity. The pioneering work done with bamboo (*D. strictus*) at the Research Centre of the West Coast Paper Mills Ltd. has shown that the above benefits can be obtained (either singly or in combination) by the addition of as small as 0.05% AQ on the basis of raw material during kraft pulping. With the encouraging results from this study, the work was extended to mixed tropical hardwoods (MHW), which are the second most important raw material for the West Coast Paper Mills Ltd. It has been shown in this paper that advantages similar to those obtained with bamboo can be realised with MHW as well. However, the amount of AQ added appears to be critical as, beyond 0.05% AQ on wood, the delignification is hindered unlike in the case of bamboo. No adverse effect has been observed in the bleachability, beating characteristics and strength properties of pulp by the addition of AQ during pulping. Black liquor properties are also not affected. These studies have shown that the addition of AQ can be very useful in the kraft pulping of bamboo and mixed hardwoods. However, plant scale trials will be necessary to confirm the laboratory results. These are being planned for both bamboo and mixed hardwoods.

INTRODUCTION

The application of different quinones in alkaline pulping of soft and hardwoods has been widely reported in literature ([1,2,3,4]). Small quantities of these compounds (typically less than 0.1% on raw material) when added during pulping have been shown to reduce alkali requirement, increase the yield and enable reductions in H-factor and sulphidity. In particular, alkylate derivatives of anthraquinone (AQ), such as 2-Methylanthraquinone, and even AQ itself, have been reported ([2]) as possessing superior performance compared to other substituted and unsubstituted quinones.

*Senior Chemist, **Research Chemist, ***Research Officer, ****Senior Research Officer, *****Works Manager, The West Coast Paper Mills Ltd., Dandeli, Karnataka.

Pulping with AQ has today generated worldwide interest. At the Research Centre of West Coast Paper Mills Ltd., pioneering work was done on the influence of AQ in the kraft pulping of bamboo, the main Indian raw material. The results have been reported elsewhere ([5]). With some differences, the results obtained were generally similar to those reported in the literature. After investigating the effect of AQ as an additive in bamboo pulping, the next logical step seemed to be to extend the investigation to mixed tropical hardwoods (MHW), which constitute approximately 40% of the raw material at West Coast Paper Mills Ltd.

The present work, therefore, deals with effects of AQ addition in the kraft pulping of MHW. The results have been compared with those obtained in the previous study with bamboo.

EXPERIMENTAL

1. RAW MATERIALS

Mill chips of MHW were used. These were a typical mixture as normally used in the mill. The following six hardwood species were present:

S. No	Botanical Name	Local Name
(i)	Adina cordifolia	Heddi
(ii)	Anogeissus latifolia	Dindal
(iii)	Dillenia pentagyna	Karmal
(iv)	Kydia calycina	Bhendi
(v)	Lagerstroemia lanceolata	Nandi
(vi)	Terminalia belerica	Ghoting

The percentage composition of the mixture was not known. The chips were air dried to about 16% moisture and screened through a Williams' chip classifier. The $-32+3$ mm fraction was accepted and stored in sealed polyethylene bags for experimentation.

2. CHEMICALS

Commercial AQ (melting point 279°C) from an Indian manufacturer was used for these studies. Cooking was generally done with mill white liquor except for special studies requiring very low sulphidity. In such cases synthetic white liquors were prepared by dissolving C.P. grade sodium sulphide and carbonate in calculated amounts of diluted caustic lye.

3. EQUIPMENT AND PROCEDURE

The bulk of the cooking was done in a Stalsvet's autoclave (bomb) digester which consisted of six s.s. bombs each of 2.5 litre capacity (charge of chips : about 200 gm o.d.) rotating in a polyglycol bath which could be electrically heated to the desired temperature. Some cooks were also performed in a Weverk "research" digester (volume 20 litres) where a larger quantity of chips (about 2.5 kg o.d.) could be cooked. This digester also had provision for liquor circulation and heating through an external electrically heated preheater.

With regard to bleaching, chlorination was done in a closed polyethylene container at ambient temperature in a fume cupboard, while other stages of the CEHH sequence were performed in polyethylene containers placed in temperature-controlled water baths.

Beating was carried out in the laboratory "Valley beater and standard handsheets of 60 ± 1 gsm were prepared in a British sheetmaking machine. These sheets were tested for various physical properties. Pulp viscosity (CED) was determined using an Ostwald viscometer placed in a constant temperature bath at 25°C.

Black liquor concentration was done in a "Toshniwal" rotary vacuum flash evaporator. The viscosity at different concentrations was determined in a "Brookfield" viscometer while calorific values of black liquor solids were found using a "Toshniwal" bomb calorimeter.

4. EXPERIMENTAL WORK

The experimental work was planned in a similar way as done for bamboo earlier [5].

It was first desired to investigate whether the addition of AQ during pulping would have any effect on active alkali requirement, kappa number, yield and rejects. For this phase of the work, several bomb cooks were performed. The active alkali charged on raw material was varied between 13 and 19% as Na_2O. At each level of active alkali, 6 (or more) bomb cooks were carried out where the AQ charge (% on o.d. chips) was varied as follows :

0, 0.025, 0.05, 0.075, 0.1, 0.3

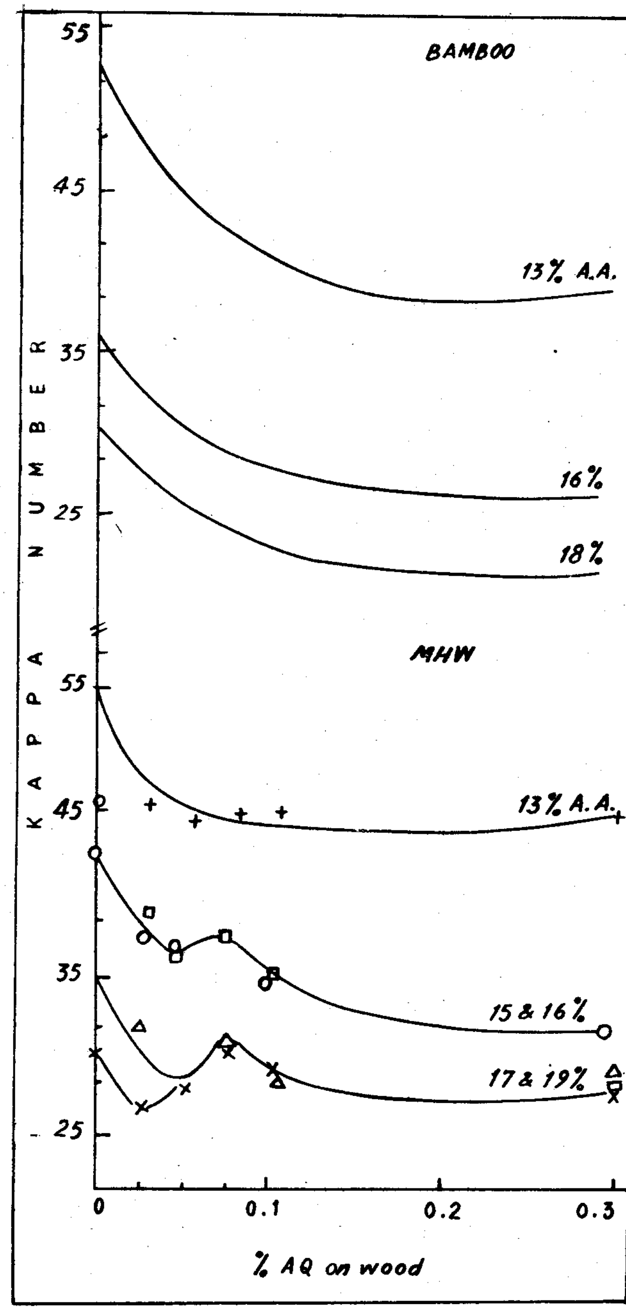

Fig. 1. Variation of Kappa No. with AQ Charge at Different levels of Active Alkali.

The constant cooking conditions were as given below:

Weight of chips per bomb	: 200 gm. o.d.
Sulphidity of liquor	: 20.2%
Heating schhedule 70 to 120°C.	: 45 min.
At 120°C.	: 30 min.
120 to 170°C.	: 120 min.
At 170°C.	: 56 min.
Total	: 251 min.
Bath ratio	: 1:2.8
H-factor	: 1300
Diluent	: Water

The results from these experiments have been summarised graphically in Fig. 1, 2, 3 & 4.

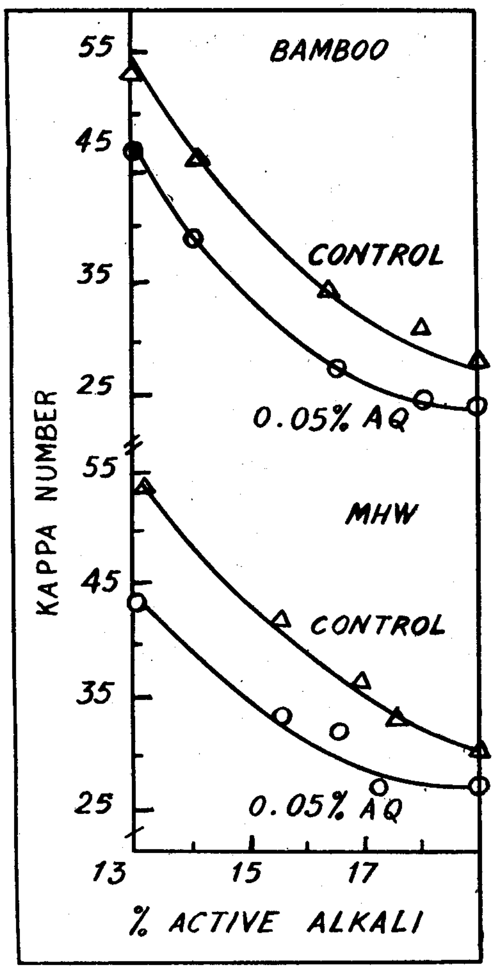

Fig. 2. Variation of Kappa No. with Active Alkali Charge.

Based on the results from the above series of experiments, the AQ charge for the rest of the experiments was taken as 0.05% on o.d. chips.

In the next phase of the work, it was decided to investigate the possibility of reducing the H-factor at constant kappa number by AQ addition. For this study bomb cooks were carried out using 17.5% active alkali on o.d. chips. The cooking temperature

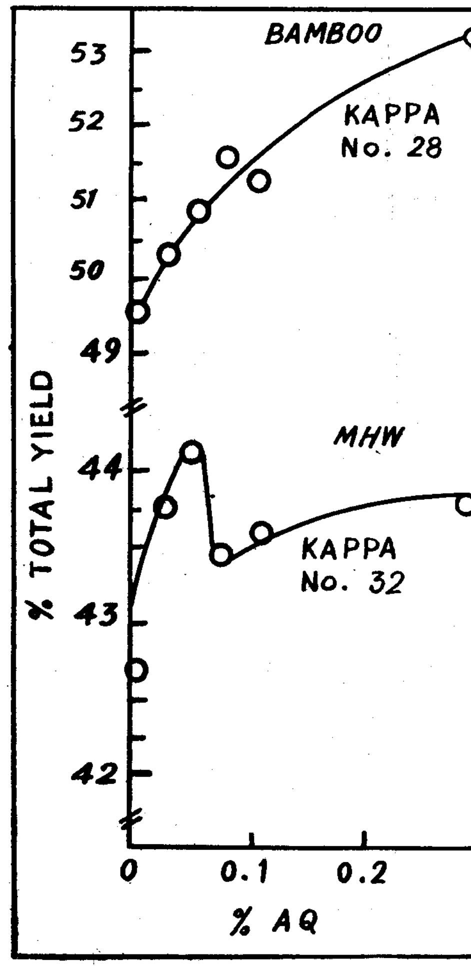

Fig. 3. Effect of AQ charge on Total Yield at Constant Kappa No.

was 170°C. H-factor was varied between 900 to 1500 by changing the cooking time (30 to 69 minutes) at this temperature. AQ (0.05% on chips) was added to all cooks except the control. For the control the H-factor was kept at 1500, which produced a number of 31.5. The cooking data are presented in Table–I. Based on this data, Fig. 5 shows kappa number–H-factor and kappa number - cook time relationship while Fig. 6 illustrates the variation of yield with H-factor.

In the next phase of the work, the possibility of reducing white liquor sulphidity under AQ addition while maintaining pulp kappa number constant was investigated. The sulphidity was varied between 0 and 37.5%. The active alkali was kept constant at 17.5% and the causticity at about 85% for each sulphidity level. Several bomb cooks were performed including control cooks and cooks with 0.05% AQ on chips. The pulping results are summarised in Table–II while Fig. 7 shows the variation of kappa number with sulphidity and Fig. 8 the relationship between yield and sulphidity.

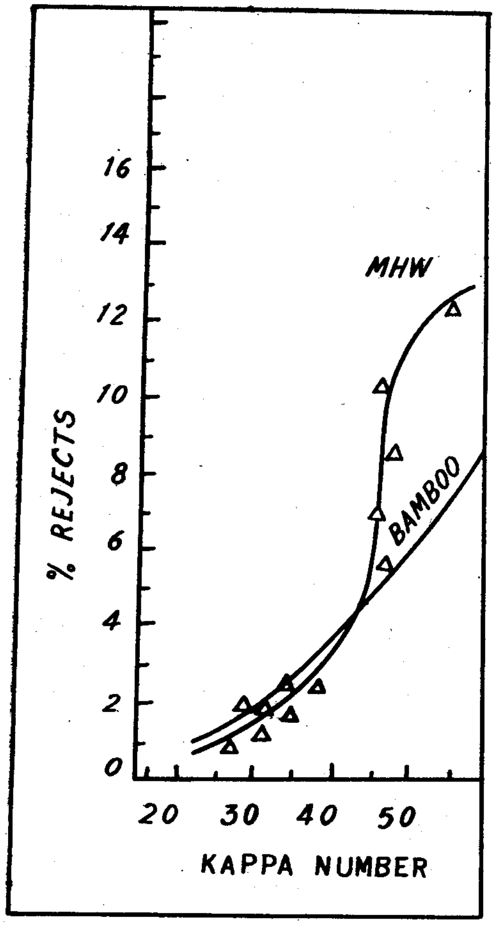

Fig. 4. Relationship Between Percentage Rejects and Kappa Number.

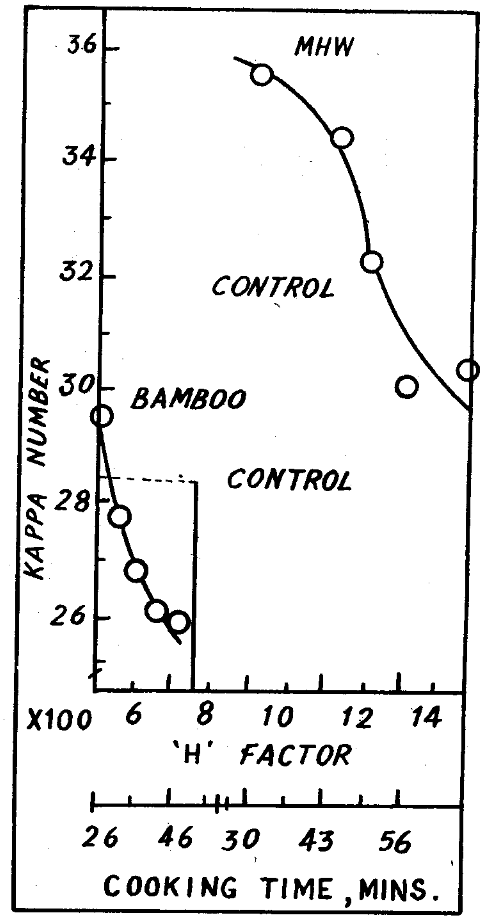

Fig. 5. Variation of Kappa Number With 'H' Factor and Cooking Time at Maximum Temperature.

After studying the effect of sulphidity variation, it was decided to check whether the charge of fresh AQ during pulping could be reduced by the recirculation of weak black liquor from a previous AQ cook as a diluent. This has been reported in the literature(6).

For this phase of the work, four bomb cooks were carried out, one with black liquor (obtained from a previous cook without AQ) as diluent and 0.05% AQ. Three other cooks were carried out with black liquor obtained from a previous cook with 0.05% AQ. The AQ charge was gradually reduced in these cooks to see the effect of black liquor recirculation. The data are recorded in Table–III.

In this final phase of this work, the effect of AQ pulping on pulp bleachability, beating characteristics and strength properties was studied. The effect of reducing the sulphidity on the bleachability of pulp was also examined by small scale bleaching experiments (CEHH sequence) to a target brightness of 80±(Elrepho). This is recorded in Table–IV. The effect of AQ on black liquor properties was also examined. Two cooks were carried out in the Research Digester with and without AQ and water as diluent. The black liquors were collected and used as diluents for two other cooks. One of these cooks served as control. Here, no AQ was added and the diluent was black liquor from the previous cook without AQ. Active alkali charged was 18.5% on o.d. chips. In the second cook, 0.05% AQ was added on chips and the alkali was reduced by 2% to 16.5% on chips. Except for alkali reduction, other process parameters were not changed. Kappa numbers around 30 were aimed at. Data for these two cooks are presented in Table–V.

The pulps from these two cooks were taken for bleaching studies. The CEHH sequence was used to get a brightness of 80±1% Elrepho. The bleaching conditions and results are recorded in Table–VI.

The unbleached and bleached pulps were individually beaten in the laboratory Valley beater and standard handsheets of 60±1 gsm were prepared in the British Sheetmaking Machine. The sheets were tested for various physical properties. The results interpolated at 30°SR are recorded in Table–VII.

The black liquors from the above two cooks were also tested for their tendency to produce "granules" upon concentration, calorific value and viscosity (Brookfield). The results are presented in Table–VIII.

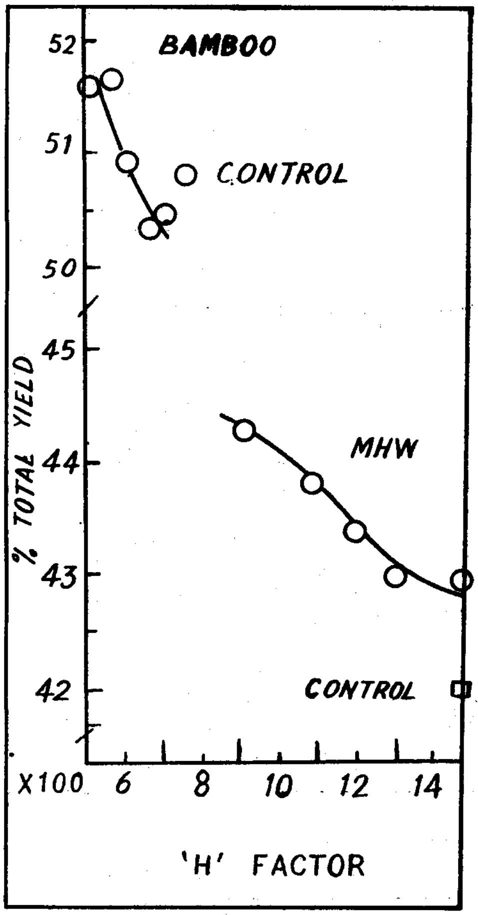

Fig. 6. Effect of 'H' Factor on Total Yield.

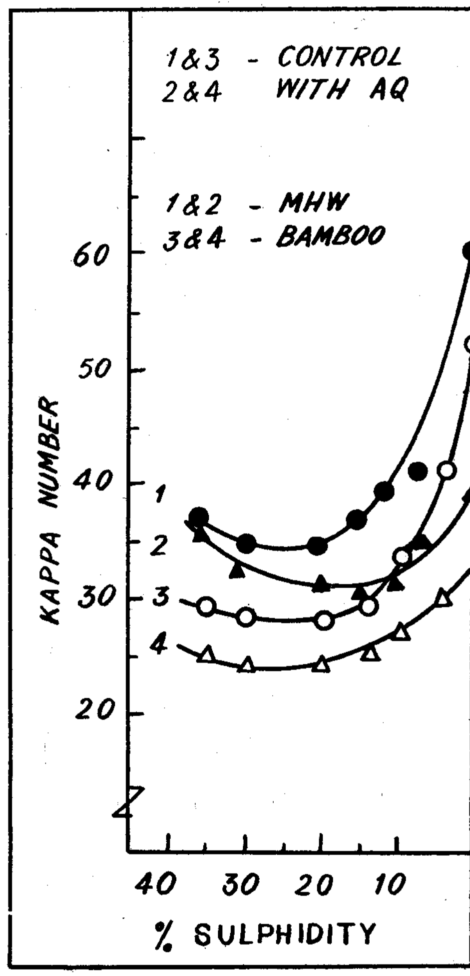

Fig. 7. Effect of Sulphidity on Kadpa Number.

DISCUSSION

EFFECT OF AQ CHARGE ON PULPING

Fig. 1 shows the variation of kappa number with increasing AQ charge at different levels of active alkali. At a low amount of active alkali, 13%, the kappa number drops sharply by about 10 units with the application of 0.025% AQ on chips. Further increase in AQ charge upto 0.3% has practically the effect in reducing the kappa number.

It can be further observed from Fig. 1 that the curves for 15 and 16% active alkali are almost over-lapping each other. Here the kappa number is seen to reduce upto 0.05% AQ charge. On increasing the AQ applied to 0.075%, the kappa number shows a tendency to increase again. On further increase of AQ charge to 0.1% the kappa number drops again to the level obtained with 0.05% AQ. Thereafter it remains almost constant upto 0.3% AQ charge.

A similar effect is observed for 17 and 19% active alkali. For 17% alkali, the kappa number drops upto 0.05% AQ. With further increase in % AQ, the kappa number increases again at 0.075% AQ, falls at 0.1% AQ and then remains constant upto 0.3% AQ on chips. The curve for 19% alkali shows minimum kappa number at 0.025% AQ, then rises and joins the curve for 17% active alkali with which it coincides.

These peaks in the curves were confirmed by carrying out duplicate cooks. They are not observed in the case of bamboo as can be seen from the curves for bamboo included in Fig. 1. It is possible that some side reactions occur in the complex mixture of tropical hardwoods that use up AQ and do not allow it to accelerate the delignification. Further work is necessary to clarify this point.

From the foregoing it may be concluded that for the present sample of MHW, the optimum AQ charge is between 0.025-0.05% on chips, depending on the level of acive alkali. In this range, AQ accelerates the delignification and reduces the kappa number at constant alkali charge.

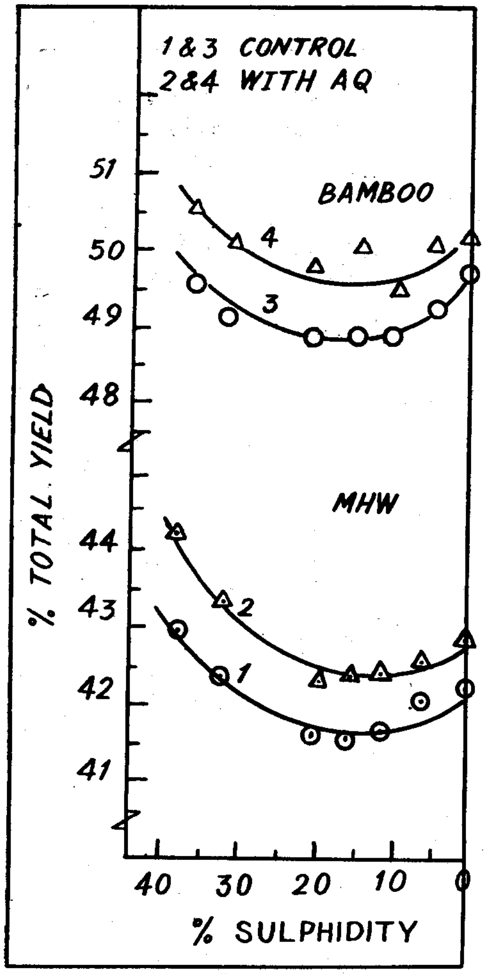

Fig. 8. Relationship Between Yield and Sulphidity.

Fig. 2 shows the kappa number—active alkali curve for control cooks and cooks with 0.05% AQ on chips. It can be seen that for every charge of active alkali, the kappa number is lower for the AQ cook than for the control. It is also clear that the addition of AQ enables a reduction in active alkali charge at constant kappa number, e.g., at a kappa number of 32, the reduction in active alkali is from 17.8 to 15.4% as Na_2O, i.e., 2.4% on chips, or about 13.5% on charge alkali basis.

Fig. 2 also shows similar curves for bamboo where, at a kappa number of 28, the active alkali can be reduced by AQ addition (0.05%) from 18.2% to 16.0%, i.e., by 2.2% on chips.

Fig. 3 depicts the relationship between the total yield at a kappa number of 32 and the AQ charge. It may be observed that the yield increases upto 0.05% AQ charge and decreases sharply at an AQ charge of 0.075% on chips, becoming almost constant thereafter. This again demonstrates that AQ loses its effectiveness beyond the critical concentration of 0.05%. At this charge, the increase in yield at a constant kappa number of 32 is about 1.5% compared to the control. Reference to the curve for bamboo (kappa number 28), included for comparison in Fig. 3 shows that no particular critical AQ charge exists. AQ is effective over the entire range although the increase in yield shows down beyond 0.05-0.07% AQ on chips.

The variation of rejects percentage with kappa number is shown in Fig. 4. The curve is normal and shows that the percentage of rejects increases with increasing kappa number. The AQ charge does not appear to have a direct bearing on the amount of rejects except at 13% active alkali, where the rejects are seen to reduce at constant kappa number under AQ addition. At other active alkali levels the rejects are governed by the kappa number. The AQ charge does not affect the rejects quantity directly. If the kappa number is reduced, then rejects also go down.

EFFECT OF H-FACTOR REDUCTION IN THE PRESENCE OF ANTHRAQUINONE

The effect of varying the H-factor on the kappa number in the presence of 0.05% AQ on chips is shown in Fig. 5. Points have been included for the control cooks as well. The curve for bamboo has been included for comparison.

It can be seen that the addition of AQ helps to reduce the H-factor by 16% at the same kappa number (31.5) as the control. The following figures, interpolated from the figure, illustrate this point :

S. No.	Pulp Particulars	Kappa No.	'H' factor	Saving in H-factor	% Saving in H-factor
1	Control	31.5	1500	..	..
2	With 0.05% AQ	31.5	1260	240	16

Thus the trend with MHW is the same as that in bamboo although the saving in H-factor for bamboo is more, of the order of 30%. H-factor may be reduced for MHW under AQ addition at constant kappa number. Fig. 5 shows that a saving of 16% in H-factor for MHW would amount to reduction of cooking time by about 16 minutes at 170°C. However, beyond an H-factor of 1300, the kappa number—H-factor relationship levels out indicating that further increase in H-factor is not useful in delignification.

Fig. 6 shows the total yield—H-factor relationship for AQ cooks and control. For both MHW and bamboo, the curves are normal, indicating that increase in H-factor brings down the yield. Beyond 1300 H-factor, the curve for MHW flattens out. This is similar to Fig. 5 where the kappa number became constant beyond this H-factor.

Fig. 6 also shows that at an H-factor of 1500, the control cook gave a pulp yield of 42% while the AQ cook gave 43%, i.e., 1% more yield. However, if the comparison is made at the kappa number of the control cook, i.e., 31.5, the increase in yield is of the order of 1.2% on chips, as shown in the table below :

S. No.	Pulp Particulars	Kappa No.	'H' factor	Total yield (%)	Increase in yield (%)
1	Control	31.5	1500	42.0	..
2	With 0.05% AQ	31.5	1260	43.2	1.2

Hence it may be concluded that, by adding 0.05% AQ on chips, it is possible to reduce H-factor by 16% and simultaneously gain 1.2% in yield at a constant kappa number of 31.5.

REDUCTION OF SULPHIDITY IN THE PRESENCE OF ANTHRAQUINONE

The relation between kappa number and sulphidity is presented in Fig. 7 for both bamboo and MHW. The sulphidity was varied between 0 and 37.5% for MHW keeping the active alkali constant at 17.5%.

For the control MHW cooks, Fig. 7 shows that the kappa number is relatively little affected by reducing the sulphidity from 37.5 to 20%. On reducing the sulphidity below 20% the kappa number rises very fast reaching a figure of 60 at zero sulphidity. For corresponding AQ cooks the kappa number is almost the same as control at 37.5% sulphidity. As the sulphidity is reduced below this level, the kappa number starts to drop below the control. At a sulphidity of 20%, the difference in kappa number is about 5 units. Between 20 and 10% sulphidity, the kappa number does not increase, in contrast to control cooks. Between 10 and zero % sulphidity, there is a 20 point increase in kappa number for the control cooks whereas the increase is much less for AQ cooks. Thus it can be concluded that, for MHW, the action of AQ becomes more and more marked as the sulphidity is reduced below 0%. The maximum kappa number reduction is obtained a zero % sulphidity, i.e., a soda cook. This is in agreement with Holton (2).

Interpolation from Fig. 7 shows that a pulp of kappa number say 34 can be produced in two ways:

(i) by using 17.5% active alkali on chips and 25% sulphidity.

(ii) by using 17.5% active alkali on chips, 5% sulphidity and 0.05% AQ on chips.

The curves for bamboo included for comparison show a similar trend to MHW except that, the kappa number for AQ cooks is lower than control even at high sulphidity, e.g., 36%. This shows that AQ is more effective in case of bamboo than MHW.

Fig. 8 shows the variation of total yield with sulphidity for AQ and control cooks. It can be seen that for MHW as well as bamboo, the AQ cooks always give a higher yield compared to control throughout the sulphidity range. It has been shown above that a MHW pulp of kappa number 34 may be produced at 25 % sulphidity without AQ or at 5% sulphidity with 0.05% AQ on chips. For these two pulps, the yields can be obtained from Fig. 8. At 25% sulphidity (control), the yield is 42% whereas at 5% sulphidity (AQ cook), the yield is 42.6%. Thus there is a slight advantage in yield at the same kappa number with the use of AQ.

Hence there is a distinct possibility of operating with a reduced sulphidity while producing a pulp of constant kappa number and at the same time of getting a slightly higher pulp yield.

Small scale bleaching experiments conducted with 50 gm pulp using the CEH sequence showed that the bleachability was the same for two pulps of the same kappa number, one produced at high sulphidity (19.8%) without AQ and the other at low sulphidity (6.8%) with 0.05% AQ on wood. The results have been presented in Table–IV. From these results it can be concluded that provided the kappa number is constant, cooking at low sulphidity in the presence of AQ does not affect bleaching characteristics or final brightness. The total chlorine requirement is solely governed by the kappa number of the unbleached pulp.

EFFECT OF RECIRCULATING ANTHRAQUINONE - CONTAINING BLACK LIQUOR AS A DILUENT DURING COOKING

Out of the total amount of AQ charged during pulping, a part goes out with the pulp and the remainder with black liquor. It seems possible, therefore, to reduce the charge of fresh AQ during pulping if weak black liquor from a previous AQ cook is used as a diluent. The object of this part of the study was to check this hypothesis.

The results of Table-III indicate that recirculation of AQ containing black liquor does not help in reducing kappa number further. This can be seen by comparing cook no. 1 & 2 in the table. However, on reducing the AQ charge to 0.045% in cook no. 3 the kappa number is decreased. This indicates that AQ recirculated with black liquor in combination with charged AQ, has helped to reduce the kappa number. This trend does not continue in cook no. 4 where further reduction of AQ charge produces pulp of higher kappa number.

The above results indicate that the charge of AQ is critical. Also, there might be some advantage in recirculating AQ-containing black liquor. Nevertheless, these results, obtained from single cooks need confirmation by further experimentation.

TABLE—I. VARIATION OF 'H' FACTOR IN THE PRESENCE OF AQ

Bomb Cook No.	1	2	3	4	5	6
AQ charge, % on O.D. chips	Nil	0.05	0.05	0.05	0.05	0.05
'H' factor	1500	900	1100	1200	1300	1500
Time at 165ºC., min.	69	30	43	50	56	69
Total pulp yield, %	42.0	44.3	43.8	43.4	43.0	43.0
Kappa Number	31.5	35.6	34.6	32.3	29.9	30.7
Black liquor T.S., % w/w	19.3	18.1	20.0	19.9	20.2	20.4
R.A.A. at 200 gpl T.S.	6.0	9.8	9.4	8.8	6.4	6.0

TABLE—II. EFFECT OF SULPHIDITY VARIATION ON PULPING OF MHW WITH AND WITHOUT AQ

Particulars	Bomb Cook Numbers													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Active alkali as Na_2O on O.D. chips %	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Sulphidity, %	0	6.8	11.3	15.4	19.8	31.6	37.5	0	6.8	11.3	15.4	19.8	31.6	37.5
'H' Factor	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
AQ addition on O.D. chips, %	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total yield, on O.D. chips	42.4	42.2	41.8	41.6	41.7	42.5	43.1	43.0	42.7	42.6	42.5	42.5	43.7	44.7
Kappa Number	59.4	40.3	39.7	35.0	34.3	34.6	35.2	38.8	34.8	31.0	34.0	30.7	33.5	36.1
Black Liquor														
Total solids, % w/w	19.4	20.1	20.4	20.9	20.3	20.8	19.4	19.3	19.8	20.5	20.2	19.9	20.3	19.9
Residual Active Alkali at 200 gpl ts.	11.4	10.0	8.4	7.8	8.6	7.8	7.4	10.8	8.8	8.6	8.6	9.0	8.0	8.0

Bath ratio=1:2.8 Diluent=Water Cooking temp., ºC.=170

TABLE—III. EFFECT OF RECIRCULATING AQ - CONTAINING BLACK LIQUOR

Particulars	Bomb Cook Numbers 1	2	3	4
Active alkali on chips, %	16.5	16.5	16.5	16.5
Cooking temp., °C.	170	170	170	170
H-factor	1300	1300	1300	1300
AQ, on chips %	0.05	0.5	0.045	0.04
Diluent	BL (without AQ)	BL (with AQ)	BL (with AQ)	BL (with AQ)
Kappa number	33.6	33.4	32.0	35.7
Total yield, %	43.5	43.7	43.1	43.3
Rejects, %	2.0	1.9	1.5	2.3

TABLE—V. LARGE SCALE LABORATORY PULPING OF MHW FOR STUDIES ON PULP AND BLACK LIQUOR

Pulping conditions	Control	With AQ (0.05% on chips)
Active alkali, % on chips	18.5	16.5
Sulphidity, %	19.8	19.8
Sulphidity, %	19.8	19.8
Diluent	Black Liquor	Black Liquor with AQ
Cooking temperature, °C.	170	170
H-factor	1600	1600
Total yield, % on chips	43.7	45.6
Rejects, %	1.4	1.6
Kappa Number	30.8	31.0
Weak Black Liqour		
Total solids, %	23.4	25.0
Residual active alkali, gpl at 200 gpl ts.	7.2	5.8

Cooking schedule:

70°C – 120°C.	=	45 Mins.
At 120°C.	=	30 "
120°C. - 170°C.	=	120 "
At 170°C. -	=	76 "

TABLE—IV. STUDY OF EFFECT ON BLEACHING OF SULPHIDITY REDUCTION IN AQ PULPING

Particulars	Control	With AQ
Sulphidity, %	19.8	6.8
Unbleached K. No.	34.3	34.8
Chlorination :		
Cl_2 added, % on pulp	6.50	6.50
Cl_2 consumed, % on pulp	6.47	6.47
Alkali Extraction :		
NaOH added, % on pulp	1.75	1.75
Final pH	9.5	9.5
Hypo I Stage :		
Cl_2 added, % on pulp	2.20	2.20
Cl_2 consumed, % on pulp	2.12	2.10
Final pH	7.0	6.9
Hypo II Stage :		
Cl_2 added, % on pulp	0.8	0.8
Cl_2 consumed, % on pulp	0.68	0.70
Final pH	7.4	7.5
Total Cl_2 added, % on pulp	9.5	9.5
Total Cl_2 consumed, % on pulp	9.27	9.27
Bleach requirement % on K.No.	27.0	26.7
Brightness, % (Elrepho)	80.0	79.5
Viscosity, cp. (CED)		
Shrinkage, %	4.8	4.6

Constant Conditions :

	C	E	H	H
Consistency, %	3.0	5.0	10.0	10·0
Temperature, °C	Ambient	55	45	45
Retention time, min.	60	60	60	60
Sulphamic acid on Cl_2 added, %	..	..	2.0	5.0

EFFECT OF AQ PULPING ON BLEACHING CHARACTERISTICS, BEATABILITY, STRENGTH PROPERTIES AND BLACK LIQUOR CHARACTERISTICS

The bleaching conditions and results have been presented in Table–VI. There do not seem to be any major differences between the control and the AQ cooked pulp. However, the control appears to consume a little more total chlorine and produces 1% lower brightness than the AQ pulp. The slightly higher viscosity of the control pulp may perhaps be ascribed to its lower brightness. However, this needs

TABLE–VI. BLEACHING OF PULPS FROM LARGE SCALE LABORATORY COOKS BY CEHH SEQUENCE

Particulars	Control	With AQ
Unbleached kappa number	30.8	31.0
Chlorination :		
Chlorine added, % (on O.D. pulp)	6.0	6.0
Chlorine consumed, % (on O.D. pulp)	5.97	5.97
Alkali Extraction :		
NaOH added, % (on O.D. pulp)	1.6	1.6
Final pH	9.5	10.0
Hypo I Stage :		
Chlorine added, % (on O.D. pulp)	2.2	2.2
Chlorine consumed, % (on O.D. pulp)	2.10	1.98
Final pH	7.2	7.0
Hypo II Stage :		
Chlorine added, % (on O.D. pulp)	0.5	0.4
Chlorine consumed, % (on O.D. pulp)	0.33	0.21
Final pH	7.5	7.6
Total chlorine added, % (on O.D. pulp)	8.7	8.6
Total chlorine consumed, % (on O.D. pulp)	8.41	8.16
Brightness, % (Elrepho)	79.2	80.1
Shrinkage, %	7.8	8.0
Viscosity, cp. (CED)	12.7	11.6
P.C. Number	7.2	6.0

Constant conditions :

	C	E	H	H
Consistency, %	3.0	5.0	10.0	10.0
Temperature, °C.	Ambient	55	45	45
Retention time, min.	60	60	60	60
Sulphamic acid added on available Cl_2, %	..	..	2.0	5.0

TABLE–VII. STRENGTH PROPERTIES OF BLEACHED HANDSHEETS AT 30 °SR

Particulars	Control	With AQ
Beating time, mins.	10.5	10.5
°SR	30	30
Drainage time (700 ml), Sec.	24.5	24.0
Bulk, cc/g.	1.20	1.20
Breaking length, kms.	5.95	6.20
Stretch, %	3.3	3.2
Double folds (MIT)	98	82
Tear factor	95	94.5
Burst factor	38.5	40.5
Strength index	1938	1942

Strength index $= [(\log \text{D.F.}) \times \text{B.F.} \times \text{T.F.}]^{\frac{1}{3}} \times 100.$

confirmation by further experiments. The yellowing tendency of the pulps as determined by the p.c. number indicated a more stable brightness for the AQ pulp, which had a lower p.c. number compared to control.

The strength properties of bleached pulps (control and with AQ) have been reported in Table–VII at 30 °SR. It is clearly seen that addition of AQ does not affect beatability or pulp properties. The strength index is identical for control and AQ cooked pulp.

The black liquor properties have been presented in Table-VIII. It can be seen that at about 40 and 50% total solids the viscosities of the black liquors from control and AQ cooks at different temperatures are practically the same. At about 60% total solids, the liquor from the AQ cook exhibits somewhat higher viscosity although this might be within the limits of experimental error.

Appearance of granular material upon concentration is a characteristic of the MHW black liquors. The "granulation point" can be seen from Table–VIII to be the same (about 37%) with and without AQ.

Also, the calorific value is not affected in any way. For both liquors, the calorific value is around 3,600 K.Cal./Kg.

TABLE—VIII. BLACK LIQUOR PROPERTIES

(i) Viscosity (Brookfield) - Total solids - Temp. – Relationship.

Control				With AQ			
Total solids % w/w	Viscosity, cp. at different temp. 80°C.	90°C.	100°C.	Total solids %w/w	Viscosity, cp. at different temp. 80°C.	90°C.	100°C.
39.0	5.7	4.5	4.0	39.6	6.0	4.5	4.2
50.6	26.0	20.0	16.4	49.4	26.0	21.0	15.0
60.0	114.0	82.0	52.0	59.3	126.0	100.0	70.0

	Control	With AQ
(ii) Granulation		
Granulation starts at :	36.4% T.S.	37.0 % T.S.
(iii) Calorific Value (KCal/Kg)	3,625	3,612

Note — The black liquor was obtained from the cooks for which data have been presented in Table–V.

CONCLUSIONS

Based on the results obtained in this study the following broad conclusions can be drawn:

1. AQ has been found to be an effective pulping additive for the kraft pulping of mixed tropical hardwoods. The charge of AQ has been found to be critical. Depending on the active alkali used, 0.025–0.05% AQ on chips has been found to be optimum. Even in such small quantities, AQ has been found to accelerate delignification.

2. It has been shown that AQ-an be used in three ways. Experiments conducted with 0.05% AQ on chips have shown that :
   (i) About 2–2.4% reduction in active alkali on chips is possible while maintaining a kappa number of about 32. Simultaneously, an yield increase of about 1.5% on wood is obtained.
   (ii) In case active alkali is not reduced, the cooking time at maximum temperature (170 °C.) can be brought down from 69 minutes to 53 minutes, i.e., a saving in H-factor of about 16%. This can be achieved at a constant kappa number of 31-32. Simultaneously, there is a gain in pulp yield to the extent of 1.2% on wood.
   (iii) If active alkali or H-factor are not reduced, than there is a possibility of drastic reduction in sulphidity while maintaining constant kappa number. At a kappa number of 34, a reduction in sulphidity from 25% to 5% is possible. A slight yield advantage is also obtained in this case, about 0.6% on wood.

3. Except at very low levels of active alkali, the % rejects do not appear to be directly related to the AQ charge. The rejects are governed by the kappa number of the pulp. At a constant kappa number, the % rejects are relatively independent of the AQ charged.

4. No major differences were observed at constant kappa number in the bleaching characteristics, beatability and pulp properties with and without 0.05% AQ on wood during pulping.

5. The addition of 0.05% AQ on wood during pulping does not have any adverse effect on the granulation tendency of calorific value of black liquor. However, at 60% total solids, the viscosity of the liquor was slightly higher than for liquor from control cooks without AQ. At lower total solids, the viscosity was the same. Experiments with recirculation of AQ-containing black liquor have indicated that it might be beneficial to use these liquors for dilution during cooking as this helps to reduce AQ charge.

The benefits of AQ addition in the kraft pulping of mixed tropical hardwoods have been discussed above. It must be mentioned here that these experiments were conducted with normal mill chips. There is wide variability in the wood being received at the Mill with respect to species, age, condition of wood, etc. Thus, further work is necessary to confirm the results reported here. However, this study has shown that there is a prima facie case for the use of AQ as an additive in the kraft pulping of mixed tropical hardwoods.

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