Economics of bamboo and hardwood pulping by anthraquinone catalysed-kraft-process

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SUMMARY

With a view to study the economy of pulping bamboo and tropical mixed hardwoods using anthraquinone, laboratory studies were conducted to confirm the benefits of AQ-addition in Kraft pulping liquor. The use of 0.05% anthraquinone in Kraft pulping reduced alkali charge by 1.8% on OD weight of chips and increased the yield by 2-2.3% at the same kappa number level. Equations for calculating net savings from AQ addition and cost savings matrices have been developed. A typical test case showed that the cost of pulp production may be reduced by Rs. 80/-per M.T. for bamboo and tropical mixed hardwoods in a medium-sized pulp mill.

While developing a certain pulping process, the cost design has to be always kept in mind; and the question "Shall we realise profit from this venture ? " needs satisfactory solution. An effort has been made by the authors to answer this question, particularly with reference to Kraft—AQ pulping of bamboo and tropical mixed hardwoods, (MHW) which are the major raw material source to paper industry in developing countries like India.

Holton [1,2] found that even small quantities of Anthraquinone (AQ) in Kraft cooking liquor improve pulp yield, reduce sulphidity demand and produce pulp of better quality. With various wood species, use of AQ in pulping has been found to have a marked catalytic effect leading to lower chemical and energy demands [3,5,6,7]. Besides enhancing the rate of delignification, AQ is said to stabilise carbohydrates[4] and at comparable kappa numbers, unbleached yield is reported to be higher for Kraft-AQ pulps [2,6,7] with seemingly no adverse effect on bleachability, beating characteristics and strength properties of bleached and unbleached pulps [6,10,11,12].

With a view to study the economy of pulping using AQ, the present work was undertaken. Following approaches of immediate interest have been made in the present work to study how far AQ would be useful in reducing the cost of pulp manufacturing:--

i) Active Alkali reduction with a simultaneous yield gain

ii) H-factor reduction with a simultaneous yield gain while increasing capacity

iii) Reduction in bleach chemical consumption with practically no yield disadvantage.

The system of low sulphidity cooking or soda-AQ cooking was not felt to be of immediate interest since Indian mills are not presently facing much environmental pressures for air pollution.

EXPERIMENTAL DESIGN & OBSERVATIONS

The experiments were designed for step reduction in active alkali charge or H-factor (time-at-temp.) to find the alkali charge & time requirement for the same extent of delignification (Kappa No.), when AQ is used in cooking liquor, compared to a control kraft cook.

Mill chips of Bamboo *(D. strictus)* & MHW from Andhra Pradesh forests (32 species consisting of mainly *Acacia auriculoformis, Anogessu latifolia, Boswelia serrata, Eucalyptus hybrid, Lannea grandis* etc.) were obtained from our mills chipper house, classified to get a chip size between ½ & 1" and used for experimentation. White liquor with 20% sulphidity adjusted using mill sulphide liquor & commercial grade Anthraquinone were used.

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Pulping was conducted in a 2.5 litre electrically heated stationery autoclave, using control through autotransformer & onoff temperature controller to control temperature within ±1°C.

13 no. cooks were carried out in all, under cooking conditions mentioned below & detailed in Table 1. Dilution ratio was so maintained that all the chips remained submerged in liquor.

TABLE—1

Raw Mat.	Cook No.	AA%	AQ%	Time hrs.	Total yield%	Rej. %	Screened yield %	Kappa No.	H. Factor
BAMBOO	B_1	14	—	2	47.20	1.2	46.00	31.8	1330
	B_2	14	0.05	2	45.85	0.8	45.05	26.5	1340
	B_3	13	0.05	2	47.50	1.0	46.50	28.7	1340
	B_4	12	0.05	2	49.80	1.0	48.80	33.0	1330
	B_5	11	0.05	2	53.78	1.8	51.98	38.3	1320
	B_6	14	0.05	1½	68.00	1.5	46.50	29.5	1020
	B_7	14	0.05	1	50.00	2.0	48.00	32.6	740
HARDWOOD	W_1	18	—	2	45.00	2.0	43.00	31.5	1320
	W_2	18	0.05	2	44.35	1.5	42.85	26.3	1330
	W_3	17	0.05	1	45.30	2.0	43.3	28.3	1320
	W_4	16	0.05	2	47.6	2.8	44.8	32.0	1340
	W_5	18	0.05	1½	45.0	2.5	42.5	27.6	1020
	W_6	18	0.05	1	48.3	3.2	45.1	33.0	720

Cooking conditions :

Dilution ratio 3.75 : 1 for Bamboo; 4 : 1 for MHW

Alkali charge (% as Na_2O on OD RM) : Varying
AQ for Kraft-AQ pulps (% on OD RM) : 0.05
Rate of temperature rise to 165°C : 1°C/min.
Time at 175°C : Varying

Kappa number, yield & rejects were determined by conventional standard methods and results are tabulated in Table-1 and also plotted in figures 1 & 2.

RESULTS & DISCUSSIONS

APPROACH—1

Active alkali reduction with simultaneous yield gain ;—With 14% AA and 1330 H-factor, Bamboo was cooked to 31.8 kappa number with 46.5% yield (control cook B-1). Under the same conditions, kappa number was found to be reduced by 5.2 units with 0.05% AQ (cook B-2). AA charge was then reduced in steps of 1% from 14% to 11% maintaining H-factor the same. It was observed that kappa number gradually increased from 26.5 to 38.3. On figure 1 by drawing a

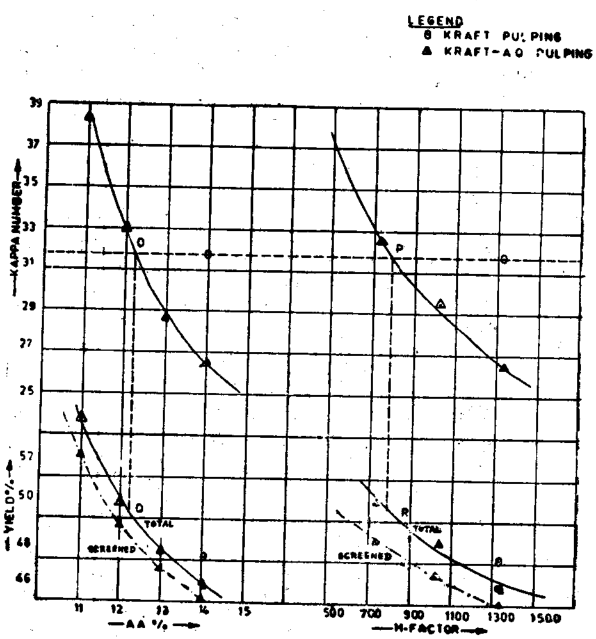

Fig.—1. Pulping Parameters of Bamboo for AQ-Catalyzed Kraft Process horizontal line at control-cook kappa number of 31.8, it was found that the line intersects the curve at 12.2% AA charge indicating a possible reduction of 1.8% in AA or 18 Kg. AA/Ton bamboo using 0.5 Kg. of AQ/Ton OD Bamboo for maintaining kappa number at the same level.

Also at 12.2% AA & 0.05% AQ, the yield was more by 2-3% as compared to control cook B-1, as seen by the intercept of vertical line OQ with yield versus alkali curve.

Similarly, in case of mixed hardwoods (fig-2), a reduction of 1.8% AA or 18 Kg. AA/ton OD MHW was possible for obtaining a kappa number of 31.5 which was equal to that of control-kraft cook W-1 when 0.05% AQ was added. Also the yield was increased by 2%.

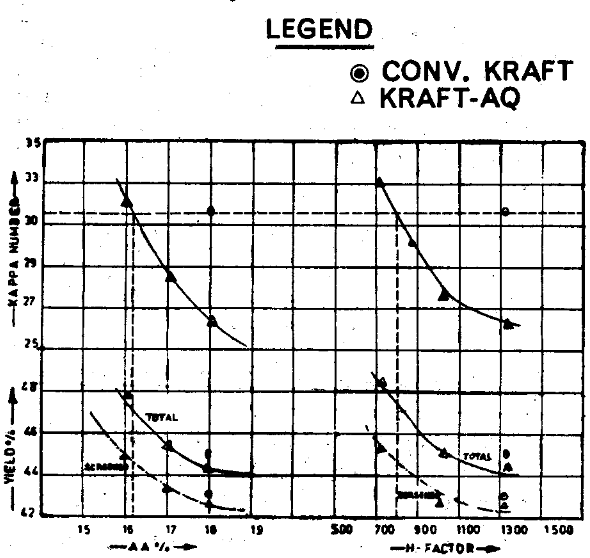

Fig. 2 Pulping Parameters of Tropical Mixed Hard Woods for AQ Catalyzed Kraft Process.

For calculating the savings in terms of money, the following equation was developed-

$$S = \frac{Q}{100}\left[y\,C_r + A\left\{ C_{SRP} + \frac{100-R}{100} \times C_{Na_2O} \right\} - AQ.C_{aq} \right]^{1}$$

Where S = net savings when AQ added in kraft pulping liquor, Rs.

Q = Quantity of OD raw materials cooked using kraft — AQ process, MT.

y = increase in yield, % on OD RM

A = reduction of active alkali charge, % on OD raw material

R = Recovery, %

AQ = Anthraquinone dosage, % on OD RM

C_{SRP} = Soda recovery plant operations cost (corrected for steam generation), Rs/MT Na_2O

C_{Na_2O} = Makeup chemicals cost, Rs/MT Na_2O

Caq = Price of Anthraquinone, Rs/MT

Cr = Price of raw material Rs/MT

Using above equation, at different recovery levels, COST-SAVINGS MATRIX were also developed for knowing the break-even line to know when the AQ-addition becomes beneficial. These matrices are based on following cost data—

Bamboo chips	(AD)	Rs. 480/- per M. T.
,, ,,	(OD)	Rs. 535/- per M. T.
MHW chips	(AD)	Rs. 400/- per M. T.
,, ,,	(OD)	Rs. 445/- per M. T.

for, 40 : 60 :: MHW : Bamboo,

∴ average OD RM cost	Rs. 500/- per M. T.
SRP operations cost	Rs. 1000/ per M. T. Na20
Makeup chemical cost,	
when salt cake used	Rs. 5500/- per M.T. Na_2O
when Caustic lye used	Rs. 6100/- per M.T. Na_2O

for, 20 : 80 : : salt cake : Caustic lye,

∴ average cost of makeup chemicals Rs. 6000/- per M. T.

Therefore, cost of Na_2O at

70% recovery level	Rs. 2800/- per M. T.
75% ,, ,,	Rs. 2500/- per M. T.
80% ,, ,,	Rs. 2200/- per M. T.

The savings equations for these costs can be written as—

$$\left.\begin{aligned} G_{70} &= 28\ A + 5\ Y \\ G_{75} &= 25\ A + 5\ Y \\ G_{80} &= 22\ A + 5\ Y \end{aligned}\right\} \quad (2)$$

Where, G is gross savings per tonne OD RM at, different recovery levels shown as subscripts to G.

In Table 3 (i), (ii) & (iii), the break even lines abc, when compared with the advantages obtained in experiments indicate that A Q addition of 0.05% on OD RM shall result in a positive value of net savings S.

Y \ A	00.5	1.0	1.5	2.0	2.5
1.0	19.0	33.0	47.0	61.0	75.0
1.5	21.5	35.5	49.5	63.0	77.5
2.0	25.0	38.0	52.0	66.0	80 0
2.5	26.5	40.5	54.5	68.5	82.5
3 0	29.0	43.0	57.0	71.0	85.0
3.5	31.5	45.5	59.5	73 5	87.0

3 (i) 70% recovery; G = 28 A + 5 Y

Y \ A	0.5	1.0	1.5	2.0	2.5
1.0	17.5	30.0	42.5	55.0	67.5
1.5	20.0	32.5	45.0	57.5	70.0
2.0	22.5	35.0	47.5	60.0	72 0
2.5	25.0	37.5	50 0	62.5	75.0
3.0	27.5	40.0	52.5	65.0	72.5
3.5	30.0	42.5	55.0	67.5	80.0

3 (ii) 75% recovery; G = 25 A + 5 Y

Y \ A	0.5	1.0	1.5	2.0	2.5
1.0	16.0	27.0	38.0	49.0	60 0
1.5	18.5	29.5	40.5	51 5	62.5
2.0	21.0	32.0	43.0	54.0	65.0
2.5	23.5	34.5	45.5	56.5	67.5
3.0	26.0	37.0	48 0	59.0	70.0
3.5	28.0	39.5	50.5	61.5	72.5

3 (iii) 80% recovery; G = 22 A + 5 Y

Table 3. Cost—Saving Matrix at different recovery levels.

(breakeven line at 0.05% AQ level abc)

Using above set of cost data and the benefits available from AQ addition in terms or reduced alkali charge & increased yield, we get from equation-1, for a 70% recovery level,

$$S_B = \frac{2.3 \times 535 + 1.8\,(1000 + 0.3 \times 6000) - 0.05 \times 50000}{100}$$

= Rs. 37/70 per ton OD Bamboo pulped

$$\& \; S_W = \frac{2 \times 445 + 1.8\,(1000 + 0.3 \times 6000) - 0.05 \times 50000}{100}$$

= Rs. 34/30 per tonne OD wood pulped.

Similar calculations cnn be made at different alkali reduction and yield gains for a particular AQ dosage

APPROACH—2

H-factor reduction with simultaneous yield gain:— In cooks B_6 & B_7 compared to cook, B_2 the time at 165°C was reduced in two steps each of 30 min. corresponding to H factors of 1020 & 740 respectively. It was observed that Kappa no. was increased from 26.5 at 1340 H-factor (cook B_2) to 32.6 at 740 H-factor. As seen in figure-1, the horizontal line at 31.5 Kappa no. intersects the curve at P indicating a possible H-factor reduction to 790 for getting a Kappa no. equal to that achieved during control-cook (B_1).

Also at H-factor 790. 0.05% AQ & 14% AA, the yield was more by about 2.3%, as compared to control cook B_1, as seen by the intercept of vertical line PR with yield H-factor curve.

Similarly in the case of mixed hardwoods (fig.2), a reduction of H-factor to 800 was possible for obtaining a Kappa no. of 31.5 which was equal to that of control kraft cook (W_1) by using 0.05% AQ with a simultaneous yield gain of about 2%.

In terms of time at 165°C, a saving of 50 mts in each cooking cycle is possible using 0.05% AQ on OD RM.

for a 160 TPD unbl. pulp mfg. unit
or 35 cooks/day each from 44 M^3 digesters

$\frac{35 \times 50}{60}$ = 29 digester hours can be saved

which is equivalent to approx. one 55 M^3 digesters. For a new unit or a mill under expansion this means a difference of an initial investment of 20 lacs. or an annual cost of $\frac{20 \times 0.95 + 20 \times 0.1}{14} = 1.357 + 2 = 3.5$ lacs

This reduction may require Rs. 35 X 5 X 300 X 50 = 26, 25, 000/- worth of AQ in one year which is even more than the total initial capital savings. Even the increased yield is not much to offset this price.

APPROACH—3

Reduction of bleaching chemical consumption :— Using a 0.05% dosage of AQ in pulping at the same AA charge, Kappa no. was found to be reduced by about 5.2 units in both the raw materials. This reduction if observed in Kappa no. & the mill Kappa no. is controlled at 26.5, the chlorine consumption is expected to be reduced by about 2.1% on unbleached pulp of 21 kg per ton unbleached pulp or approximately 10 kg on OD RM.

For liquid chlorine @ Rs. 1200/- per M.T.
& Hypo chlorite @ Rs. 1680/- per M.T.
& 40 : 60 : : liq. Cl_2 : Hypo, avg. cost of chlorine Rs. 1490/- per ton.

a gain of Rs. 15/- per ton OD RM is available from using AQ worth Rs. 25/- even neglecting a yield loss of about 1%.

CONCLUSION

The AQ addition in Kraft liquor although found to reduce the active alkali charge, or H-factor (time of cooking at 165°C) coupled with a yield increase or reduce chlorine requirement in bleaching, the use of AQ was found to be economical only when we reduce active alkali charge for maintaining mill Kappa no. at the same level. Typically, cost of pulp production may be reduced by Rs. 80/- per ton using a 0.05% AQ dosage on OD RM under the cost-conditions described in the paper.

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