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Oxygen delignification of soda and soda–AQ bagasse pulps

DINESH MOHTA, J. S. UPADHYAYA, S. K. KAPOOR, A. K. RAY, AND D. N. ROY

ABSTRACT

Addition of a small fraction (0.1% on ovendry raw-material basis) of anthraquinone (AQ) during soda pulping of bagasse reduced pulp kappa number by almost 40% (from kappa no. 21.5 for soda pulp to kappa no. 13.3 for soda–AQ pulp) at constant H-factor. Extended delignification of soda and soda–AQ pulps with oxygen further reduced the kappa numbers by almost 50% (to 11.8 and 6.8, respectively). Yield loss during oxygen delignification was marginal for both soda and soda–AQ pulps. Oxygen-delignified pulps suffered slight losses in viscosity and fiber strength, but brightness increased significantly. The lower kappa numbers of oxygen-delignified pulps will significantly reduce chemical demand during bleaching, which is both economically and environmentally sound.

Application:

Investigates the effect of extended oxygen delignification on the kappa number and strength properties of soda and soda–AQ bagasse pulps

ENVIRONMENTAL PROTECTION HAS become a dominant issue, and new governmental regulations—reflecting pressure from society—are forcing the industry to change the way chemical pulps are produced and bleached *(1, 2)*. The organic chlorine compounds formed during the bleaching of chemical pulp have attracted most of the attention during recent years. Earlier measures taken by the pulp industry to solve the chlorine problem focused on improving effluent treatment methods, i.e., measures external to the process. Today, the emphasis of research in this area has shifted more towards improving the processes themselves. The goal is to increase the efficiency and selectivity of pulping processes, thus reducing the amount of lignin in the pulp delivered to the bleach plant.

Considering the environmental impact of chlorine, it is imperative to restrict its use to the minimum extent possible in bleaching processes. Because the amount of chlorine required is directly related to the kappa number of the pulp to be bleached *(2, 3)*, the foremost need is to look into the cooking process and to explore possible remedial solutions for reducing pulp kappa number while maintaining pulp qualities. Batch digesters—particularly the RDH (rapid-displacement heating) or Superbatch processes—are among the alternatives available to the industry. However, such process changes require extensive retrofitting, which has limited their usefulness in the capital-constrained paper industry. Because the delignification process has its own limitations, the most suitable ecofriendly way of achieving a low kappa number could be through the use of an additive during cooking or through extended delignification of pulp in the presence of molecular oxygen.

Among the additives used to improve the yield and quality of soda pulp, anthraquinone (AQ) has given encouraging results. It is believed that AQ is still the most cost-effective sulfur-free accelerator for alkaline pulping. The soda–AQ process also offers a direct advantage of eliminating the air pollution associated with the kraft process *(4–6)*.

Oxygen delignification has played an important role in reducing chemical consumption in bleach plants. Pulp lignin content can be reduced by up to 50% with oxygen delignification. The presence of alkali plays an important role in oxygen delignification, and an optimum alkali dose of 1.5–2.5% on ovendry (o.d.) pulp is used. Two disadvantages to the use of oxygen are (a) its tendency to attack carbohydrates as well as the lignin and (b) the difficulty in getting oxygen to the reaction site within the fiber wall. Among the factors governing selectivity in oxygen delignification, one of the most important is the transition-metal-ion content of the pulp, since these ions catalyze the generation of harmful radical species. One approach to dealing with the problem is to remove the metals by acid washing prior to oxygen delignification. Another is by adding compounds to the pulp that inhibit carbohydrate degradation. The protector of greatest commercial importance is the magnesium ion, which is normally applied at levels as low as 0.05–0.1% (as Mg^{2+}, o.d. pulp basis). Another advantage of oxygen delignification is a reduction in the discharge of pollutants, since the dissolved solids are washed from the oxygen-delignified stock and recycled to the pulp mill recovery system *(7–11)*.

The objective of the present study was to investigate the effect of extended oxygen delignification on the kappa number and strength properties of soda and soda–AQ bagasse pulps under otherwise conventional pulping conditions.

	Soda	Soda–AQ
Alkali charge, % NaOH (as Na_2O on o.d. bagasse)	12	12
AQ dosage, % on o.d. bagasse	…	0.1
Bath ratio	1:5	1:5
Cooking temp., °C	165	165
Time to 100°C, min	30	30
Time to max. temp., min	60	60
Time at max. temp., min	60	60
H-factor	720	720

I. Process conditions for soda and soda–AQ pulping of depithed bagasse

	Soda	Soda–AQ
Pulp yield, %	53.6	50.5
Screened yield, %	50.1	49.3
Screen rejects, %	3.5	1.2
Kappa number	21.5	13.3
Viscosity, dm^3/kg	900.0	860.0
Fiber strength index (Pulmac zero span), km	10.1	9.9
Pulp brightness, % ISO	35.6	37.2

III. Results of soda and soda–AQ pulping

EXPERIMENTAL

Pulping of bagasse

Bagasse is an important raw-material resource for pulp and papermaking in India. It has all the requisite properties to replace conventional raw material (i.e., wood) for the economical manufacture of high-grade paper.

Whole bagasse was procured from an integrated mill in northern India. Dry and wet depithing of the bagasse was done in a pilot plant, which removed almost 80% of the total pith present in the whole bagasse. The final composition of the bagasse was 79.7% useful fibers, 13.6% pith, and 6.7% water solubles.

The depithed bagasse was pulped in a 0.2-m^3, rotary-type, electrically heated laboratory digester using 12% sodium hydroxide (as Na_2O, on o.d. depithed bagasse). Pulping conditions are given in **Table I.** For soda–AQ pulping, a dose of 0.1% AQ (on o.d. depithed bagasse) was charged with the alkali. Pulping conditions were otherwise the same as for the conventional soda pulps, as seen in Table I.

The soda and soda–AQ pulps were washed separately on a laboratory flat washing system with a double-fold cloth (300 mesh) placed on the wire mesh. Later, the pulps were washed thoroughly with fresh water on a Buchner funnel under suction. Washing was continued until the filtrates were colorless and the pads were slush dry. Later, the pulps were screened over a vibratory screen with 0.15-mm slots.

Oxygen delignification of bagasse pulps

The soda and soda–AQ pulps were delignified with molecular oxygen in the 0.2-m^3 rotary digester. Oxygen was injected through a valve in the digester lid. The mixture of pulp, alkali, and magnesium sulfate was heated to 55°C, and the oxygen was introduced into the digester until it gave a rise of 5 kg/cm^2 to the initial pressure of the digester at 55°C. The process conditions of oxygen delignification are given in **Table II**.

Pulp properties

Pulp kappa numbers were determined according to TAPPI T-236 os-76.

The SCAN C15:62 method was used to determine the CED intrinsic viscosity of pulps by using a capillary-tube viscometer at 25°C.

The fiber strength index (FSI) of different pulps was determined according to CPPA useful method D.27U:4P (Aug. 92) using a Pulmac zero-span instrument *(12)*.

For calculating tear and tensile indices, the pulps were beaten in a stainless-steel PFI mill under standard conditions as per ISO DP 5264. Handsheets were made as per ISO DP 5269 and dried on plates in standard conditions. Handsheets were then conditioned at 27±1°C and 65±5% relative humidity and tested according to ISO standards.

Alkali charge, %	2.5
$MgSO_4$ charge, %	1.0
Consistency, %	10.0
Oxygen dosage, kg/cm^2	5.0
Temp. at time of O_2 discharge, °C	55
Maximum temperature, °C	115
Time to max. temp., min	30
Time at max. temp., min	60

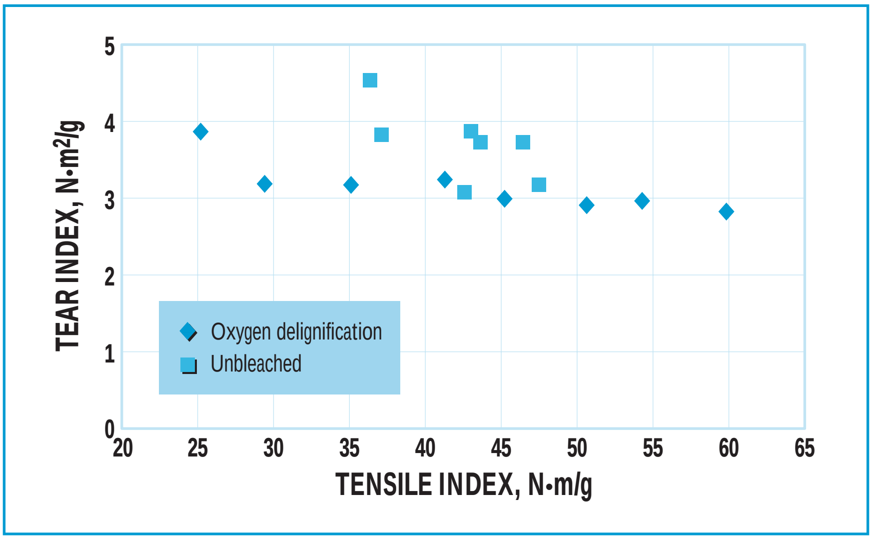
II. Process conditions for oxygen delignification of soda and soda–AQ bagasse pulp

RESULTS AND DISCUSSION

Soda and soda–AQ pulping of bagasse

The results for soda and soda–AQ pulps are shown in **Table III**. Under the same alkali charge, the soda–AQ process produced a pulp of kappa no. 13.3, much lower than the kappa no. 21.5 obtained after the conventional soda cook. The results show that pulp kappa number in the presence of AQ was 40–45% lower than for the conventional soda pulp. The screened yield for the soda–AQ pulp was only slightly lower than that of the conventional soda cook (49.3% vs. 50.1%). The viscosity for the two pulps was similar, 900 dm^3/kg for soda pulp and 860 dm^3/kg for soda–AQ pulp.

The higher rate of delignification in the presence of anthraquinone is reflected in the production of soluble lignin with a higher phenolic hydroxyl content, which indicates more extensive cleavage of ether linkages *(13)*. Therefore, in the presence of AQ, if the *H*-factor is maintained at



1. Tear index vs. tensile index for unbleached and oxygen-delignified bagasse soda pulp

	Soda	Soda–AQ
Brownstock screened yield, %	50.1	49.3
Loss of yield during O_2 delignification, %	1.7	1.2
Net yield after O_2 delignification, %	48.4	48.1
Kappa number	11.8	6.8
Viscosity, dm³/kg	820.0	790.0
Fiber strength index (Pulmac zero span), km	9.0	8.9
Brightness, % ISO	45.0	49.9

IV. Results of oxygen delignification of soda and soda–AQ pulps

the reference pulping conditions, one would expect that the extent of delignification would be greater.

The fiber strength index, calculated from the Pulmac zero-span tester, was 10.1 km for soda pulp and 9.9 km for soda–AQ pulp.

Oxygen delignification of soda and soda–AQ pulps

The results after oxygen delignification are given in **Table IV**. The delignification leveled off at kappa nos. 11.8 for soda pulp and 6.8 for soda–AQ pulp. Thus oxygen delignification removed about half of the remaining lignin in the soda and soda–AQ pulps. This reduction in kappa number reduces the chlorine demand during bleaching, and oxygen delignified soda–AQ pulp would require only about one-third of the total chlorine demand of soda pulp.

Viscosities decreased from 900 dm³/kg to 820 dm³/kg for soda pulp and from 860 dm³/kg to 790 dm³/kg for soda–AQ pulp, showing that there is a slight loss in pulp strength following oxygen delignification. The fiber strength index after oxygen delignification was 9.0 km for soda pulp and 8.9 km for soda–AQ pulp. Both are lower than their original values, a further indication that exposure to oxygen weakens the fibers.

Figure 1 is a plot of tear index vs. tensile index for unbleached and oxygen-delignified bagasse soda pulps. The oxygen-delignified pulps have slightly lower tear values at a given tensile than the unbleached pulp. This confirms that there is some fiber weakening during oxygen delignification.

The results in Tables III and IV also show that brightness of soda and soda–AQ pulps improved significantly after oxygen delignification.

KEYWORDS

Oxygen, delignification, soda pulps, bagasse, anthraquinone, kappa number, viscosity, mechanical properties.

SUMMARY

It is possible to produce bagasse pulp of low kappa number without changing the *H*-factor by introducing a small fraction of anthraquinone (0.1% on o.d. basis of raw material) during soda cooking. Both soda and soda–AQ bagasse pulps showed excellent response to oxygen delignification under alkaline conditions.

The results of the present study can be summarized as follows:

- The kappa number of soda–AQ pulp was 38% less than that of soda pulp.
- The viscosities of soda and soda–AQ pulps were almost same, indicating that AQ was selective and did not attack the carbohydrates.
- Oxygen delignification further reduced the kappa number of soda and soda–AQ pulp by 45% and 49%, respectively.
- The viscosities of oxygen-delignified pulps suffered a slight loss during oxygen delignification, indicating a slight loss of strength. This was confirmed by a graph of tear index vs. tensile index.
- A drop in the fiber strength index after oxygen delignification showed the effect of exposing fiber to molecular oxygen during delignification.
- The brightness of soda and soda–AQ pulps increased significantly after oxygen delignification.
- The chlorine demand for bleaching of oxygen-delignified

soda–AQ pulp will be only about one-third that of soda pulp. TJ

Mohta and Roy, Faculty of Forestry, University of Toronto, 33 Willcocks St., Toronto, ON, Canada M5S 3B3. Upadhyaya and Ray, Institute of Paper Technology, Saharanpur 247 001, U.P., India. Kapoor, Central Pulp and Paper Research Institute, Saharanpur 247 001, U.P., India.

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