Bleaching of Non-wood Soda-AQ Pulps using Enzymes from a Thermophillic Fungus

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ABSTRACT

An assessment of xylanase treatment prior to bleaching of different non-wood soda-anthraquinone pulps has been done. The xylanase treatment reduced the kappa number and increased viscosity and brightness. The ClO_2 requirement was reduced to about 4-11% with xylanase treatment. Xylanase treated DED and DEDP bleached pulp showed higher brightness as compared to non-treated pulps. The physical properties of treated pulp were also found to have improved.

INTRODUCTION

The growing public concern regarding environmental impact of pulp bleaching generated during is giving rise to technological change in pulp bleaching. Chlorinated phenolic compounds are toxic and resistant to biodegradation (1-3). Therefore, it is of urgent need to reduce or eliminate the use of elemental chlorine in pulp bleaching and to develop a new bleaching technology that does not produce environmentally damaging effluents.

Recently, application of oxygen delignification, chelation and hydrogen peroxide oxidation, ozonation etc. prior to bleaching reduced chlorine requirement of pulp bleaching. Interest is growing in enzyme delignification prior to bleaching as it has produced very encouraging results (6). Xylan creates a physical barrier to chlorine and sodium hydroxide accessibility to the lignin. In addition there is evidence that xylan and lignin are chemically bound (7). Various explanations have been proposed as to how the enzyme works. Firstly, it increases the fibre swelling which facilitates refining, which in turn results in better physical properties (8). Secondly, it is possible that xylanase cuts these linkages, thereby enhancing lignin removal during bleaching. Thirdly, the xylanase is supposed to hydrolyze the xylan in the fibre, thus enhancing the free penetration flow of bleach chemicals into it. Tolan and Voga (5) observed that xylanase, used as a simple treatment of softwood unbleached pulp, has the same delignification and brightening capacity as 5 to 7 kg/t of ClO_2. Jan et al. (8) showed that xylanse treated oxygen delignified hardwood kraft pulp reached 87.7% brightness with a viscosity of 17.5 mPa.s by DEDP bleaching sequence but without xylanase treatment the brightness was 85.7 with a viscosity of 15.8 mPa.s. Similar encouraging results were obtained for softwood kraft pulp. Prasad et al. (10) observed that the bagasse mechanical pulp produced brightness after peroxide bleaching of 2-3 points higher for xylanase treated pulp.

No report of xylanase per-treatment on non-wood soda-anthraquinone (AQ) pulp is available in literature. In this paper, we focus on the effect of xylanase on jute, Saccharum spontaneum, maize and cotton stalk soda-AQ pulps in DED and DEDP bleaching sequences.

EXPERIMENTAL

Pulping

Jute, Saccharum spontaneum, maize stalk, cotton stalk pulps were prepared in a laboratory electrically heated digester by soda-AQ process using optimum pulping conditions. The details of the pulping conditions and pulp properties are shown in Table 1. Optimum pulping conditions were derived previously in our laboratory.

Enzyme production

The xylanase preparation was done in solid state fermentation with wheat bran by a thermophillic fungus. The culture filtrate was used as crude source of enzymic xylanase and was found to contain mostly endo xylanase activity (2 IU/ml). The enzyme units

Table 1. Pulping conditions and pulp properties

Raw Material	Jute	S. spotaneum	Maize stalk	Cotton stalk
Pulp yield	60.5	54.2	49.6	44.8
Kappa number	12.8	18.0	19.1	32.6
NaOH, %	16	14	14	20
AQ, %	0.05	0.05	0.05	0.1
Time, h	1	1	1	1
Temperature, °C	170	170	150	170

were quantified against birchwood xylan and one unit of xylanase was defined as the amount of enzyme releasing 1 μmol of xylanase equivalent per minute under experimental conditions (11).

Pulp bleaching with enzyme

Pulps were disintegrated in a standard disintegrator by 1500 revolutions at room temperature. The pulp suspensions were filtered in a Buchner funnel and then placed in a polyethylene bag for enzyme pretreatment. The enzyme treatment was carried out at 10% consistency with a xylanase charge of 2-units/g o.d. pulp and pH was maintained at 5 by adding 4 N H_2SO_4. The treatment was run for 2 h at 50°C. After enzyme treatment pulps were washed with distilled water. Treatment of all pulps in the control sequences was carried out under identical conditions without xylanase. The kappa number of all pulps was then determined according to Tappi test methods T 236. Pulp viscosity was determined at 0.5% concentration in cupriethylene diamine (CED) (T 230 om-89).

DED bleaching

Xylanase treated and control pulps were bleached using kappa factor 0.22. During the chlorine dioxide stage, the pulp consistency was adjusted to 3.5%. 100 o.d. grams of pulp was stirred in a vessel at 400C using a thermostatically control water bath for 1 hour. Following to the chlorine dioxide stage, pulps were washed at 1% consistency and filtered using suction. A caustic extraction was carried out immediately after the washing stage with 2% NaOH on o.d. pulp at 10% consistency in a polyethylene bag. The extraction time was 1 h for 70°C. The details of bleaching conditions are given in Table 2.

Hydrogen peroxide bleaching

Peroxide bleaching of xylanase treated and control DED pulps were carried out in a water bath. Pulps were thorougly mixed with alkaline hydrogen peroxide liquor in a polyethylene bag at 10% consistency. The following conditions were maintained during this operation: 2% H_2O_2, 3% $NaSiO_3$, 0.05 $MgSO_4$, 1% NaOH (all based on o.d. pulps), time being 2 hours and at 60°C. Finally, the pulp was dispersed at 1% consistency and pH was adjusted to 5 with 4N H_2SO_4 prior to brightness measurement.

Pulp testing

Handsheets of test pulps were prepared with Korthen sheet making machine using 2 grams o.d. pulp according to German Paper Chemists and Engineers No. 106. The breaking length (T 404 Om-92), burst

Table 2. Bleaching conditions of non-wood soda-AQ pulps

Treatment	Chemical charge	Treatment time min	treatment temp., °C	pH	Consistency, %
X	2 units/g of pulp	120	50	5	10
D_1	Using 50% of K factor 0.22	60	40	2.5-3.0	3.5
E	2% NaOH on pulp	60	70	~12	10
D_2	Using 50% of K factor 0.22	60	40	2.5-3.0	3.5
P	2% H_2O_2, 3% $NaSiO_3$, 0.05% $MgSO_4$	120	60	~11	10

Table 3. Brightness of non-wood xylanase treated and control pulps after DED and DEDP bleaching sequences.

Bleaching Sequence	Jute		S. spotaneium		Maize stalk		Cotton stalk	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control
DED	81.3	78.9	80.2	78.2	80.0	77.9	80.9	78.8
DEDP	85.6	81.4	83.7	81.2	83.1	80.1	84.0	80.3

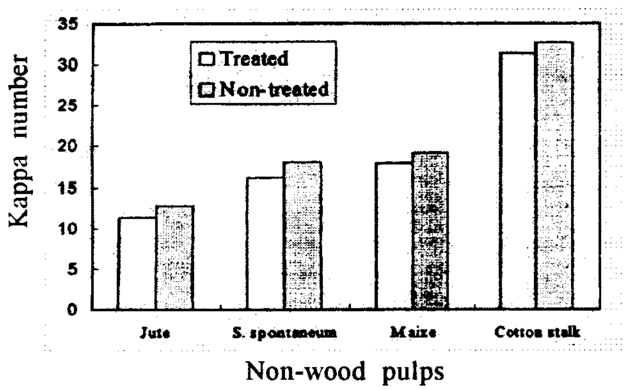

Fig. 1 Effect of xylanase on the delignification of non-wood pulps

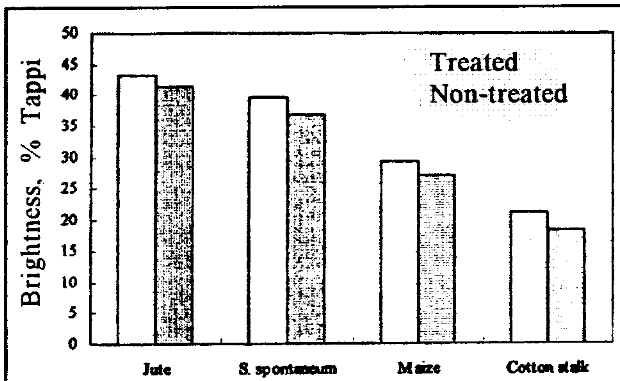

Fig. 3 Effect of enzyme treatment on the brightness of non-wood pulps

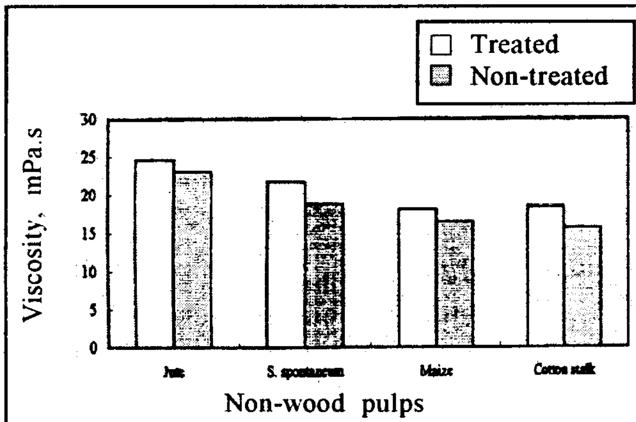

Fig. 2 Effect of xylanase on the viscosity of non-wood pulps

index (T 403 om-91), tear index (T 496 Om 85) and double fold number of experimental pulps were determined according to Tappi test methods.

RESULTS AND DISCUSSION

Although the benefit of xylanase pretreatment in chlorine dioxide bleaching of kraft pulps are well established. its application to non-wood soda-AQ pulp has yet to be studied. In the present study non-wood soda-AQ pulps were treated with xylanase. The effects of xylanase treatment were better for both before and after subsequent bleaching. Xylanase treatment of non-wood pulps decreased kappa number and increased brightness and viscosity. Fig 1-3 show the kappa number reduction and viscosity and brightness increase for xylanase treatment of non-wood pulps. The kappa number reduction was 1.2. 1.8, 1.2 and 1.4 point (Fig. 1) and viscosity increase was 2.8, 2.9, 1.6 and 1.2 mPa.s (Fig. 2) for cotton stalk, Saccharum spontanem, maize stalk and jute respectively. The improvement in viscosity confirmed that there was an enhancement of the high molecular weight cellulose fraction that occurred when xylan was selectively removed (12, 13). Similar result was also observed by other workes (14). After xylanase treatment brightness increase of non-wood pulps is shown in Fig. 3. The brightness increased from 18.3 to 21.1 for cotton stalk, 36.8 to 39.7 for S. spontaneum, 27.2 to 29.2 for maize stalk and 41.4 to 43.2 for jute on xylanase treatment of unbleached non-wood pulps.

To explore the bleachability of these pulps, each sample was subsequently treated with DED and DEDP bleaching sequences. Table 3 shows the brightness of treated and control non-wood pulps after DED and DEDP bleaching sequences. On the enzyme pre-treatment combined with DED bleaching sequence the brightness exceeds to 80% while in non-treated pulp it reaches to about 78%. The kappa factor for the D_{100} was 0.22 for all pulps. Xylanase treated DEDP bleaching responded slightly more favourably.

Table 4. Physical properties of the treated and control non-wood bleached pulps.

	Jute		S. spotaneum		Maize stalk		Cotton stalk	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control
Breaking length, meter	2378	1770	2317	1842	3765	3359	3143	2510
Burst index, $kPa.m^2/g$	1.5	1.4	1.4	1.2	2.4	2.3	2.6	1.7
Tear index, $mN.m^2/g$	9.4	8.0	9.2	7.8	6.0	5.8	4.6	4.9
Double fold number	3	2	11	8	15	9	6	3
Freeness °SR	15	13	18	15	25	23	21	18

The brightness increase after DED and DEDP sequences were 2.4 and 3.2 for jute, 2.0 and 2.5 for Saccharum spontaneum, 2.1 and 3.0 for maize stalk and 3.1 and 3.7 cotton stalk pulps, respectively (Table 3).

One of our objectives was to quantify the reduction of bleaching chemicals. To achieve 80% brightness chlorine dioxide dosage was decreased by enzyme treatment on non-wood pulps. The chlorine dioxide saving was 10.9, 10, 6.3 and 3.7% for xylanase treated jute, S. spontaneum, maize stalk and cotton stalk, respectively. Peroxide treatment was not needed to reach 80% brightness.

Physical properties of xylanase treated and control for fully bleached (DEDP) soda-AQ non-wood pulps are shown in Table 4. From these results it is seen that xylanase did not adversely affect the strength properties of the pulps even exylanase treated bleached pulps were to control bleached pulps, initial freeness in °SR of all pulps was higher than the control pulps. The increase in freeness is probably due to fibrillation of the fibres facilitate to increase the fibre bonding thereby increasing physical properties of the treated bleached pulps (Table 4). The breaking length, burst index and tear index of treated non-wood bleached pulps were 34, 7 and 17.6 for jute, 25.8, 16.7 and 18% for S.spontaneum, 12, 4.3 and 3.4% for maize stalk and 25, 53 and 6.5% for cotton stalk, respectively higher than the control pulps.

CONCLUSION

Xylanase treatment prior to bleaching decreased the kappa number of non-wood pulps to baout 1-2 points thereby saved to about 4-11% ClO_2. Xylanase treatment increased the pulp viscosity and initial brightness of all non-wood pulps studied. Treated non-wood pulps reached brightness to 90% before peroxide treatment. The physical properties of the enzyme treated pulps are higher than the non-treated pulp.

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