Effect of Kappa Number on the Bleaching Response of Soda and Kraft Pulps from Bagasse

Subrahmanyam, S.V., Sharma, A.K., Godiyal, R.D., Janbade, V.T. and Gupta, H.K.

ABSTRACT

Bagasse is used by small, medium and big paper mills in India. The fiber line operations are different depending on the capacities of the mills. Hence, it is imperative to standardise the pulping and bleaching operations, keeping the merits of the processes and economic considerations and the requirement of mills of different capacities of the mills in view. The present study on bagasse pulping and bleaching of the pulp produced evaluates the merits and deficiencies of Kraft and soda pulps with special reference to bleach plant effluent in addition to strength and optical properties of the pulps. The studies indicated that it is advisable to produce pulps with a kappa number around 15 for bleach grades. Kappa numbers below 15 have not shown any significant benefit in terms of bleaching requirement, pulp strength and bleach effluent quality.

INTRODUCTION:

The paper mills in India are broadly catgorised in to three groups ie. Big (>100 TPD); Medium (30-100 TPD); and Small (<30 TPD) and total number being $\simeq$ 500. Paper industry is considered to be one of the major contributors to gaseous and liquid pollution. The environmental norms are becoming more stringent due to public awareness. The major toxic liquid pollutants are the chloro-organics in bleach streams, since the chlorine in various forms is used in the bleaching process. Shortage in wood supply and the forest regulations and prohibitive cost of pulpwood made the technocrats to opt for agro residues as a major furnish in the papermaking. The bagasse is the prime raw material in the non-wood based fiber, which is available for the Indian paper industry. Due to its sustained availability all over the country makes the raw material a choice fiber to the paper industry. A good number of Indian mills of different capacities are using bagasse to produce bleached varieties. The fiberline operations vary from Soda pulping, Alkaline sulphite pulping and Kraft pulping. In general, the pulps produced are bleached by following CEH/ CEHH bleaching sequences. Oxygen delignification is one of best choice to significantly improve the pulp as well as effluent quality (Rajesh, K.S. et al, 2000). But it may not be practically feasible for the entire Indian paper industry to implement ECF and TCF processes by using chlorine free chemicals like Oxygen and Hydrogen peroxide. Hence, it is imperative to judiciously use existing bleaching processes to make the mills more productive without sacrificing the product quality. Keeping these limitations in view, the present work was carried out on bagasse Kraft and Soda pulps of different kappa number and CEH bleaching sequence in order to find out the optimum process conditions like kappa number of the unbleached pulp, impact on pulp quality, environmental and cost considerations. Similar studies were already conducted on other raw materials like rice straw (Gupta et al., 1988) and wheat straw (Gupta et al, 1992) and optimum kappa number for the bleachable grade pulp have been established for the better quality of the pulp and economical consideration.

Pulp Morphology:

Pulp from sugar cane (*Sachharum officinarum*) residue, commonly known as bagasse contains diverse cell types. The fibers are up to 4000 μ in length with an average of about 1750 μ. The fiber width ranges from 10 to 60 μ with an average of 23 μ. They are thick to thin walled, usually with straight, pointed ends with relatively more numerous

Central Pulp & Paper Res. Inst.,
PO Box 174,
Saharanpur - 247 001(UP) INDIA

slit-like or lenticular pits.

The wider fibers are usually shorter, frequently with blunt, oblique or forked ends. Parenchyma cells are very abundant, usually appreciably larger. They are up to 900 μ in length with an average of 375 μ and up to 180 μ in width with an average of 100 μ, and serve to easily identify bagasse. Vessels have length ranging from 180 to 1600 μ (average 600 μ) and 30 to 220 μ (mean 100 μ) in width. Epidermal cells are narrow and rectangular with undulating. Stomata may also be rarely present.

EXPERIMENTAL METHODS:

The bagasse raw material was collected from Sarsawa Sugar Mill near Saharanpur. The whole bagasse dry depithed in the laboratory. The pith content of whole bagasse was 21.4%. The bagasse used in the present experiments is assessed for its chemical composition to verify the quality of bagasse.

Pulping:

Soda and Kraft pulps were prepared in the laboratory using depithed bagasse. Kraft liquor with 19% sulphidity was used for pulping. Different chemical dosages were applied to obtain pulps in the Kappa number range of 10 to 35.

Pulping conditions:

Ambient to 100°C	30 min
100°C to 168°C	90 min.
At 168°C	90 min
Bagasse (each bomb)	200g OD
Bath ratio	1 : 5

Bleaching:

Bagasse pulp was bleached using CEH bleaching sequence to ≃ 85% ISO brightness using the following conditions:

CEH bleaching sequence:

Cl_2 Stage Consistency	:	3%
Retention time	:	30 min
Temperature	:	Ambient
pH	:	< 3
Alkali extraction consistency	:	8%
Retention time	:	60 min
Temperature	:	65°C
pH	:	≃ 10
Hypo stage Consistency	:	8%
Retention time	:	120 min
Temperature	:	40 °C
Final pH	:	≃ 9

Standards followed for testing:

Kappa number	T-236-OS-76
Bauer & McNett fiber classification	T-233-OS-75
Pentosan	CPPRI method
Viscosity	Scan C15:62
Brightness	ISO:2470

RESULTS AND DISCUSSION:

The whole bagasse was collected from a sugar mill in baled form. The whole bagasse was depithed in the laboratory and chemical proximate analysis was conducted on whole bagasse, depithed bagasse and the pith. The depithed bagasse has 71.3% holo-cellulose content (Table 1). The acid insoluble lignin in depithed bagasse is slightly on the higher side as compared with the samples collected analysed in different location (Mishra et.al. 1994). The variations in the chemical composition in bagasse are possibly due to variety of bagasse and location influence.

Table 1. Chemical Proximate analysis of Bagasse

Sl.No.	Property	Unit	Bagasse	Depithed	Pith
1	Moisture	%	26.8	26.2	24.5
2	Ash	%	1.8	1.7	2.2
3	Cold water solubility	%	1.4	1.3	8.1
4	Hot water solubility	%	3.1	2.8	9.7
5	1%NaoH solubility	%	28.9	25.8	39.9
6	Holo-cellulose	%	70.2	71.3	64.3
7	Pentosans	%	26.4	25.5	16.2
8	Acid insoluble Lignin	%	25.2	24.9	23.2

Table 2. CEH Bleaching of Kraft and soda pulps from bagasse

Dosage as NaOH	Unbleached Pulp					CEH Bleaching										
	Yield,	Screen rejects	Kappa no	Pento san	viscosity (unbld.) pulp	Cl_2 dosage	Res. Cl_2	Alkali Extr,	Hypo as Cl_2	Res. Cl_2	Bld Yield	Pentos ans	Viscosi ty (Bld)	Bright -ness	P.C.	Visco sity drop
%	%	%		%	cm^3/g	%	ppm	%	%	ppm	%	%	cm^3/gm	%	No.	%
Soda Pulp																
12	48.2	0.5	34.8	22.1	907	6.95	2900	3.0	3.0	240	43.5	19.5	430	85.4	1.55	52.6
14	45.9	0.4	28.4	22.0	886	5.67	2840	2.5	2.5	160	41.9	18.1	426	85.1	1.45	51.9
16	43.2	0.3	19.3	20.7	863	3.85	2560	2.0	2.0	140	39.8	20.3	430	87.7	1.37	50.2
18	42.1	0.2	15.5	19.4	857	3.10	2500	1.5	1.5	80	39.5	18.8	453	84.9	1.34	47.1
20	41.7	-	13.7	18.1	849	2.74	900	1.5	1.5	-	39.3	15.3	488	85.0	1.37	42.5
22	40.4	-	12.4	17.6	795	2.47	640	1.5	1.5	-	38.2	16.6	392	84.1	1.56	50.7
Kraft Pulp																
8	54.3	0.6	49.1	24.5	1073	9.82	380	3.5	3.5	40	48.5	18.7	591	86.5	0.85	44.9
9	52.4	0.4	33.4	22.3	1023	6.68	360	3.0	3.0	30	47.7	17.6	576	87.4	0.92	43.7
10	49.9	0.2	25.1	21.5	945	5.02	300	2.5	2.5	40	45.9	17.4	556	87.2	0,65	41.2
12	48.0	0.1	15.0	21.3	890	3.00	85	1.5	1.5	30	45.1	17.4	551	87.3	0.67	38.1
14	44.0	0.0	11.0	21.1	756	2.20	90	1.5	1.5	20	41.5	18.7	504	86.0	1.56	33.3
16	40.6	0.0	10.3	19.8	741	2.07	50	1.5	1.5	10	38.5	17.8	481	85.4	1.17	35.1

The depithed bagasse was cooked in laboratory digester using different chemical doses so as to obtain soda and Kraft pulps having kappa numbers in the range of 10 to 35 (Table 2). The yield levels reduced with reduction in kappa number in general. The yield levels of Kraft pulps are comparatively on the higher side to the yield from the soda cooking at any given kappa number. The pentosan content in the pulps is better preserved in Kraft pulping compared to soda pulping (Table 2). The cellulose degradation is also low in Kraft pulping as compared to soda pulping as indicated by the intrinsic viscosity of the pulps.

Table 3. Pulp yield and raw material requirement to produce one Bone dry Ton Bleached pulp.

Sl. No.	Chemica l dose	Screen Yield	Kappa No.	Chlorine dose		Shrinkage	Bleached yield	Raw material/ BD Ton Pulp
	%	%		Ele. Cl_2	Hypo (Cl)	%	%	Ton
Soda as NaOH								
1	12	48.2	34.8	6.95	3.0	9.8	43.5	2.30
2	14	45.9	28.4	5.67	2.5	8.7	41.9	2.39
3	16	43.2	19.3	3.85	2.0	7.9	39.8	2.51
4	18	42.1	15.5	3.10	1.5	6.2	39.5	2.53
5	20	41.7	13.7	2.74	1.5	5.7	39.3	2.54
6	22	40.4	12.4	2.74	1.5	5.5	38.2	2.62
Kraft as Na_2O								
7	8	54.3	49.1	9.82	3.5	10.6	48.5	2.06
8	9	52.4	33.4	6.68	3.0	8.9	47.7	2.10
9	10	49.9	25.1	5.02	2.5	8.1	45.9	2.18
10	12	48.0	15.0	3.0	1.5	6.0	45.1	2.22
11	14	44.0	11.0	2.2	1.5	5.6	41.5	2.41
12	16	40.6	10.3	2.07	1.5	5.1	38.5	2.50

Kraft and soda pulps with different kappa number were bleached using CEH sequence in such a way that pulps would attain a brightness level ~85% ISO. The total chlorine requirement for Kraft and soda pulps varied from a minimum of 4% to a maximum of 10% depending up on the kappa number of the pulp (Table 2). It was observed that the residual chlorine level in the bleach effluents from soda pulps in elemental chlorine stage to be extremely high. The Kraft pulps on the other hand generated bleach effluent with considerably lower chlorine level. Similar trends were observed in residual chlorine levels in hypo stage bleach effluents. These observations indicate that the Kraft pulps respond more efficiently to CEH bleaching.

Cost analysis:

The bleached yields of the soda pulps are in the range of 43.5% to 38.2% (Table3). The requirement of fibrous raw material to produce one ton of bone dry bleached pulp from bagasse using soda process varies from 2.3 tons to 2.62 tons (Table 3). The cost analysis of bleach pulp production from soda pulping indicates continuous increase in cost as the kappa number of the pulps reduces. Since the environmental regulations are becoming more stringent on requirement is about 18% to produce a pulp with 15 kappa. The bleached pulp produced using 15 kappa pulp has good intrinsic viscosity and lowest brightness reversion (Table4). The bleached yield of the Kraft pulps fall in the range of 48.5% to 38.5% in the present study. The fiber requirement for producing one ton of bone dry bleached bagasse pulp using Kraft process varies from 2.06 tons to 2.50 tons (Table 3). The cost analysis of bleach pulp production from Kraft process was carried out assuming 80% chemical recovery of pulping chemical. As evident from table 4, the cost of bleached pulp gradually reduced with reduction in kappa number up to 15. Lowering of pulp kappa below 15 has negative impact on the production cost. The quality of bleached pulp from 15 kappa Kraft pulp is superior (Table 4). The strength of 15 kappa pulp is good as indicated by the intrinsic viscosity of the pulp. The brightness reversion is also lowest for this pulp (Table 4).

The above observations indicate that in the light of stringent environmental regulations on the quality of liquid effluent discharges, the Indian pulp and paper industry is left with no choice other than producing low kappa pulps. The chloro-organics in effluents can only be reduced by lowering the chlorine usage (Kumar, S. et al. 1999) or by splitting the chlorine doses. Production of low kappa pulps

Table 4. Cost of raw material, pulping and bleaching chemicals per ton of bleached pulp

Sl. No.	Raw material		Pulping chemical		Bleach chemicals Chlorine						Total cost	AOX generation	Visco sity	P.C. No.
Un it	Ton	Cost (Rs.)	Kg	Cost (Rs.)	Caustic (Kg)	Cost (Rs.)	Cl_2 gas (Kg)	Cost (Rs.)	Hypo as Cl_2 (Kg)	Cost (Rs.)	Rs.	Kg/Ton	Cm^3/g	
Soda Pulping														
1	2.30	4,600	276.0	3864	33.27	466	77.07	771	33.27	50	9,611	6.96	430	1.55
2	2.39	4,780	334.6	4684	27.43	384	62.20	622	27.42	41	10,511	5.68	426	1.45
3	2.51	5,020	401.6	5622	21.68	304	41.73	417	21.68	33	11,396	3.86	430	1.37
4	2.53	5,060	455.4	6376	15.98	224	33.01	330	16.00	24	12,014	3.10	453	1.34
5	2.54	5,080	508.0	7112	15.90	223	29.04	290	15.90	24	12,729	2.74	488	1.37
6	2.62	5,240	576.4	8070	15.87	222	28.99	290	15.87	24	13,846	2.48	392	1.56
Kraft Pulping														
7	2.06	4,120	164.8	328	39.17	548	109.89	1,099	39.17	59	6,154	9.82	591	0.85
8	2.10	4,200	189.0	378	33.00	462	73.48	735	33.00	50	5,825	6.68	576	0.92
9	2.18	4,360	218.0	436	27.23	381	54.67	547	27.23	41	5,765	5.02	556	0.65
10	2.22	4,440	266.4	533	15.99	224	31.98	320	15.99	24	5,541	3.00	551	0.67
11	2.41	4,820	337.4	675	15.90	223	23.32	233	15.90	24	5,975	2.20	504	1.56
12	2.50	5,000	375.0	750	15.23	213	21.01	210	15.23	23	6196	2.06	481	1.17

Cost (in Rs.) of raw materials considered are – Bagasse @ 2,000/ton; NaOH @ 14/kg; Chlorine gas @ 10/kg; Hypo @ 15/kg; Salt cake @ 10/kg

AOX discharge levels (Gupta et al, 1998), the Indian pulp and paper industry is left with no options other than reducing the chlorine consumption. Reducing the kappa number of the pulp, as it has empirical relation with AOX formation, can only control AOX formation. Hence, the desired kappa number in this case is below 15. The soda from conventional soda process is not feasible with the existing know-how, due to the extent of chemical losses. So, the Kraft process with chemical recovery is the only viable alternative today keeping in view the cost of pulp production, quality of product and environmental considerations.

CONCLUSIONS:

1. Kraft pulps respond with better brightness and low reversion level compared to soda pulps at any given kappa number and chlorine consumption.
2. Loss in viscosity of Kraft pulps during bleaching is low compared to those of soda pulps.
3. Residual chlorine levels of Kraft pulp bleaching is significantly lower compared those of soda pulps.
4. Kappa number has significant effect on AOX production levels due to lower chlorine requirement.
5. Pulps with a kappa number around 15 are ideal for CEH bleaching to meet the product quality requirement and environmental regulations.

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