Effect of Anthraquinone on Alkaline Sulphite Pulping of Jute (JRC-321 Variety)

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ABSTRACT

Cooking trials by alkaline sulphite (AS) process were carried out with jute fibre (W_5), 33% upgradation of JRC -321 variety) at different ratios of sodium sulphite to sodium hydroxide. Pulping experiments were conducted at cooking chemicals of 6.4% Na_2SO_3 and 2.33% NaOH (both as Na_2O), and adding different doses of anthraquinone (AQ) for improving pulping properties. The effect of AQ on the different doses of sodium sulphite and sodium hydroxide were carried out. All pulping experiments were done under same liquor ratio (1:4), cooking temperature (160°C) and cooking time (3hr.). Strength properties of both unbleached and bleached pulps were evaluated. The process offered the advantages of obtaining higher strength properties and higher yield of bleached pulp at lower chlorine concentration. It was found at 3.87% (as Na_2O) alkali concentration that AQ was effective in giving higher yield and more delignification than that in pulp where no AQ was used. However, at this alkali concentration, it produced pulp of reddish colour having higher permanganate number.

INTRODUCTION

Neutral sulphite and alkaline sulphite processes are generally conducted for wood pulping by semi-chemical, chemi-mechanical and chemi thermo-mechanical processes (1-3). However previous works (4-5) indicate that alkaline sulphite process is suitable for cooking non-wood fibrous material for obtaining high grade bleachable pulps.

High grade pulps which have high brightness, cleanliness and strength, are generally prepared from soft wood but due to non-availability of this raw material, Indian Paper Industry is dependent on the imported soft wood pulp. The existing forest resources, which are already in shortage, are barely able to sustain the forest production rate. On the other hand,the demand of wood for pulp production has affected the natural ecosytem and environment due to deforestation. One of the promising nonwood material for making high quality pulp is jute fibre, which consists of individual fibre with average fibre length of 2-3mm and 20 microns diameter. It has been proved that jute fibre of white variety is finer than tossa variety and among the various white varieties, fibre from JRC-321is the finest known today. Our previous work (6) on making high quality pulps from higher graded (W_4-W_3) JRC -321 jute variety by moderate alkaline sulphite process (AS) using NaOH and Na_2SO_3 as cooking chemicals already has been published. It has been observed that anthraquinone is most effective in highly alkaline pulping condition viz., kraft and soda process (7-9) where it acts by accelerating delignification and protecting the carbohydrate as a giving the benefit of higher yield and low bleachability. Extensive work has been done on effect of anthraquinone on jute fibre by kraft, soda (10-11) and neutral sulphite processes (12). We have prepared pulp (13) of high yield (66-70%), strength and brightness (80-85% P.V.) from jute (JRC-321 variety) by mild alkaline sulphite process. However, studies (14) have indicated that alkaline sulphite in addition to anthraquinone process has many advantages. In our present study, attempts have been made to examine the effect of anthraquinone in different doses in mild alkaline condition for improving the pulping characteristics.

Table 1. Results of pulping in different concentration of chemicals

Cook	Na_2SO_3 (as Na_2O) %	NaOH (as Na_2O) %	Anthra quinone %	Yield of pulp %	Perman-ganate No.	Residual Na_2SO_3	Total solid %	pH of Cooking liquor	pH of black liquor
1	4.93	2.33	-	70.00	18.00	Nil	12.50	10.50	6.50
2	4.93	2.33	0.20	69.67	17.00	Nil	13.00	10.50	6.50
3	6.40	1.55	-	71.80	19.10	0.13	12.00	11.00	7.50
4	6.40	1.55	0.50	69.40	18.00	0.19	13.00	11.00	7.50
5	6.40	2.33	-	69.70	17.00	0.22	13.10	11.50	8.00
6	6.40	2.33	0.05	68.80	16.50	0.20	14.00	11.50	8.00
7	6.40	2.33	0.10	68.00	16.10	0.20	15.18	11.50	8.00
8	6.40	2.33	0.20	68.10	16.00	0.09	14.80	11.50	8.00
9	4.93	3.87	-	69.00	25.00	0.03	13.40	12.00	8.50
10	4.93	3.87	0.10	70.50	22.00	0.03	12.20	12.00	8.50
11	6.40	3.87	-	65.64	23.00	0.13	15.58	13.00	9.00
12	6.40	3.87	0.10	69.00	18.40	0.13	13.80	13.00	9.00
13	7.874	1.94	-	69.50	18.00	1.26	13.80	11.50	8.00
14	7.874	1.94	0.25	69.20	17.50	1.18	13.00	11.50	8.00

Table 2. Results of bleached AS and AS-AQ pulps

Cook No.	Na_2SO_3 (as Na_2O) %	NaOH (as Na_2O) %	Brightness unbleached pulp	Anthra quinone %	Total Cl_2 used %	Bleached pulp Yield %	Bleached pulp Brightness	Bleached pulp Copper no.
1	4.93	2.33	33.80	-	7.88	93.00	77.00	0.82
2	4.93	2.33	36.00	0.20	7.26	96.00	77.20	0.80
3	6.40	1.55	51.00	-	7.90	93.00	85.30	1.10
4	6.40	1.55	49.40	0.50	7.16	95.50	83.30	1.00
5	6.40	2.33	43.00	-	5.796	93.20	80.00	0.90
6	6.40	2.33	40.50	0.05	5.86	94.10	81.50	0.92
7	6.40	2.33	40.00	0.10	5.54	94.60	78.50	0.86
8	6.40	2.33	39.00	0.20	5.47	95.40	80.00	0.90
9	4.93	3.87	29.80	-	7.85	93.50	83.60	1.04
10	4.93	3.87	26.40	0.10	7.01	94.82	82.50	0.97
11	6.40	3.87	39.20	-	7.77	92.30	83.00	1.10
12	6.40	3.87	34.00	0.10	5.80	93.50	82.00	1.05
13	7.874	1.94	54.00	-	8.90	92.50	86.50	1.30
14	7.874	1.94	53.00	0.25	7.80	94.00	85.00	0.98

Table 3. Strength properties of Cooks 1 and 2

Cook	Pulping	Unbleached Sheet					Process	Bleached Sheet				
			45	30	15	0	Beating Time min	0	15	30	45	
			45	34	26	18	Freeness °SR	18	25	35	48	
			1.56	1.6	1.67	1.5	Consistency %	1.66	1.43	1.53	1.5	
			62.7	62.7	62.3	77.3	Substance (g)/m²	66.8	63.4	63	63.3	
			6.9	4.92	4.12	2.76	Burst Index	1.65	2.82	4.7	5.4	
1	AS		76.86	69.06	52.74	27.45	Tensile Index	20.78	44.31	57.06	68.63	
			18.72	20.6	22.06	22.84	Tearing Index	17.55	19.2	16.76	16.1	
			3.94	3.56	3.12	2.87	Stretch %	2.87	3.19	3.56	3.87	
			>2000	>2000	818	47	Folding endurance	18	256	925	1220	
		55	45	30	15	0	Beating Time min	0	15	30	45	
		53	45	36	28.5	20	Freeness in °SR	16	26	30	45	55
		1.52	1.52	1.57	1.48	1.65	Consistency %	1.67	1.66	1.58	1.56	1.52
		67.4	66.5	64.4	64	63.5	Substance (g)	66	61	61	65.2	63
		7.35	6.94	4.7	4.41	2.3	Bursting Index	1.8	3.43	4.04	7.40	7.41
2	AS-AQ	78.53	71.76	68.2	56.7	27.02	Tensile Index	25.74	50.35	67.25	79.2	83.8
		21.23	22.4	23.14	26.34	29	Tearing Index	16.64	23.14	21.21	17.45	15.56
		4.44	4.25	3.81	3.25	2.87	Stretching %	2.87	3.5	4	4.12	4.37
		2145	2060	1746	1615	68	Folding endurance	48	824	1296	1758	2235

EXPERIMENTAL

Pulping studies

Jute fibre (JRC-321 variety, W_5-33% upgradation) was collected from Purnea (Bihar). The whole fibres including bark and dust were chopped to the required size (2.5 inch in length). The chopped material was mixed uniformly and 1.5 Kg air dry material was packed in several packets. At the same time the moisture content of the material was estimated.Moderate alkaline sulphite (AS) pulping of the above air dry packed (1.5 kg) material was separately done in a 10 litre capacity electrically heated laboratory stainless steel rotary digestor with and without addition of anthraquinone (AQ). The work involved the different ratios of sodium sulphite to sodium hydroxide under same cooking time (3hr.), cooking temperature (160°C) and liquor ratio (1:4). After cooking, the black liquor was collected by filtering through 100 mesh sieve and analysed for total solid content, residual sulphite and pH of the liquors. The cooked pulps were first washed with water and simultaneously, defibrilation and washing were done in a Valley Beater. The washed pulps were then used for determining yield, Permanganate no. and brightness of unbleached sheets. The pulping parameters and their results are shown in Table 1.

Bleaching Experiment

A four stage (CEHH) bleaching sequence was followed for each type of alkaline sulphite pulp (AS), and alkaline sulphite pulp with addition of anthraquinone (AS-AQ). All bleaching experiments were done under same conditions. In the chlorination stage, the pulps were treated with 60% of the total required chlorine at 30±2°C for 60 min. at 5% consistency and of 2-3 p H. After chlorination the pulp was washed thoroughly with water. Then the alkali extraction was done with 2% NaOH at 9% consistency for 60 min. at temperature of 55-60°C. Again the pulp was washed and used for hypochlorite bleaching stage. In the first hypochlorite treatment, 20% of the total required chlorine was used. This experiment was done at 7% consistency for 60 min. at 45-50°C.The pH of this pulpslurry was maintained at 8-9 during bleaching time. For the second stage hypochlorite treatment, same procedure was followed as in the first stage hypochlorite treatment.

Table 4. Strength properties of Cooks 3 and 4

Cook	Pulping	Unbleached Sheet					Process	Bleached Sheet				
		60	45	30	15	0	Beating Time min	0	15	30	48	
		64	50	37	28.5	17.5	Freeness °SR	19.5	29	41.5	63	
		1.43	1.42	1.46	1.5	1.52	Consistency %	1.63	1.53	1.48	1.48	
		61.3	60.6	59	59	64.7	Substance (g)	62	56.5	58	64	
		7.22	7.12	6.66	5.54	1.8	Bursting Index	2.3	5	6.6	7.14	
3	AS	74.63	67.16	66.67	46.53	19.46	Tensile Index	24.8	47.86	64	69	
		19.5	20.7	22.16	26	16.66	Tearing Index	19.41	21.2	18.1	17.45	
		4.56	4.12	5	3.87	3.12	Stretch %	3.94	3.75	4.25	4.25	
		>2000	>2000	>2000	1380	8	Folding endurance	17	456	>2000	>2000	
		60	45	30	15	0	Beating Time min	0	15	30	45	60
		59	41.7	92.4	22.5	16.1	Freeness in °SR	16.5	29.5	36	53	68
		1.38	1.34	1.35	1.35	1.48	Consistency %	1.49	1.48	1.47	1.46	1.47
		62.5	63.8	65.0	63.5	59.6	Substance (g)		65.2	59.5	60.2	62.7
		7.0	7.1	5.5	4.7	1.88	Bursting Index		3.2	6.22	6.1	6
4	AS-AQ	80.78	75.6	66.86	48.63	24.5	Tensile Index		40	65.9	66.5	69.06
		22.1	21.2	21.72	20.22	19.1	Tearing Index		23.43	24.2	19.2	18.14
		4.62	4.2	3.75	3.12	3.31	Stretching %		4.12	5.37	5.12	4.94
		>2000	>2000	>2000	369	16	Folding endurance		1040	>2000	>2000	>2000

After completing the bleaching experiment, the yield of bleached pulp, brightness, copper number and total chlorine consumption were estimated. The results are shown in Table 2.

Pulp evaluation

Unbleached and bleached paper sheets were prepared from each type of AS and AS-AW pulps by Sheet Making Machine. The moist sheets were pressed in between blotting papers under autocompression for 3 and 5 minutes respectively at 3.5 Kg/cm^2 pressure. Then the sheets were dried in air. The physical strength properties of both unbleached and bleached air dry sheets for different beating times were evaluated. These strength properties for both AS and AS - AQ pulps are shown in Table 3 for the cooks 1 and 2, in Table 4 for the cooks 3 and 4, in Table 5 for the cooks 5,6,7 and 8 where different doses of AQ are used and in Table 6 for the cooks 13 and 14 respectively. The strength properties of the cooks (9 to 12) were not found out but it may be considered from the pulping characteristics shown in Table 1 and 2 that the strength properties would not be much different from the other strength properties estimated.

RESULTS AND DISCUSSION

The pulping results at different chemical concentrations on addition of different doses of AQ are shown in Table 1. From these experimental results, it is seen that except the cook numbers 9 to 12, there is no improvement of yield but better cooking with lower permanganate number can be obtained by using AQ in the cooking liquor. Probably at low alkali concentration, AQ has no effect in protecting the carbohydrate matter during the cooking stage. In case of cook numbers 9 to 12, where higher alkali concentration (3.87% as Na_2O) is used, AQ is more effective in incresing the yield and better delignification. In other words, AQ acts as a catalyst for protecting the carbohydrate matter and accelerating delignification inspite of using lower dose of sulphite. However permanganate numbers of these cooked pulps are slightly higher in comparison to those of other cooks (1 to 8, 13 and 14) because, at high alkali dose, a reddish colour is developed after washing the cooked

Table 5. Strength properties of Cooks 5, 6 and 7

Cook	Pulping	Unbleached Sheet					Process	Bleached Sheet				
		60	45	30	15	0	Beating Time min	0	15	30	45	60
		45.5	36.5	33	20.5	16	Freeness °SR	16.5	22.5	31	40.5	53
		1.51	1.51	1.53	1.67	1.67	Consistency %	1.69	1.57	1.54	1.53	1.52
		63.4	64	62	60.5	x	Substance (g)	x	61.5	63	61.6	67.7
		8.7	8.14	6.53	4.47	x	Bursting Index	x	3.98	5.9	7.27	7.3
5	AS	81.96	70.5	61.3	54	x	Tensile Index	x	42.51	60.2	70.6	77.45
		19.48	20.21	22.45	25.12	x	Tearing Index	x	22.94	19.3	16.86	16.1
		3.75	3.25	2.32	1.7	x	Stretch %	x	1.75	3.44	3.25	3.87
		>2000	>2000	>2000	604	x	Folding endurance	x	290	>2000	>2000	>2000
		60	45	30	15	0	Beating Time min	0	15	30	45	60
		50	39	28.5	21	16.5	Freeness °SR	17	23	29.5	38	47
		1.49	1.5	1.5	1.52	1.58	Consistency %	1.57	1.54	1.53	1.51	1.49
		58.6	55.4	57	54.6	55	Substance (g)	57	59.2	54.3	59.2	61.7
		8.65	8.64	7.765	4.86	2.44	Bursting Index	1.88	3.64	5.6	5.6	8.2
6	AS-AQ	99.8	93.82	78.82	68.82	30.3	Tensile Index	22.06	52.745	72.35	76.47	82.11
	(.05%)	16.1	18.4	18.57	19.02	12.84	Tearing Index	13.43	16.57	15.88	14.53	13.98
		3.81	3.37	2.87	2.5	1.75	Stretching %	1.69	3.12	3.43	3.7	3.68
		895	1016	728	390	16	Folding endurance	12	246	635	1200	2496
		60	45	30	15	0	Beating Time min	0	15	30	45	52
		47	37	28.5	21.5	16	Freeness in °SR	16.5	22.5	33	44	50
		1.52	1.52	1.53	1.56	1.56	Consistency %	1.52	1.52	1.5	1.5	1.49
		54	54	56	54	56.4	Substance (g)	57	58	57	55.6	55
		8.65	7.53	6.5	4.8	2.51	Bursting Index	1.72	3.12	4.99	6.50	7.4
7	AS-AQ	92.16	79.9	69.12	59.02	31.76	Tensile Index	18.92	45.34	69.36	84.3	76.1
	(0.1%)	18.16	18.88	20.3	25.4	20.85	Tearing Index	14.45	22.314	19.95	18.7	19.25
		3.8	3.5	3.15	2.5	1.87	Stretch %	2	2.69	3.44	3.88	3.30
		1970	1685	1460	520	16	Folding endurance	5	304	748	1150	1040

Contd..... (Table 5)

Table 5. (Continued) Strength properties of Cooks 5, 6 and 7

Cook	Pulping	Unbleached Sheet						Process	Bleached Sheet				
		75	60	45	30	15	0	Beating Time min	0	15	30	45	60
		50	40.5	32	23	19	15.5	Freeness in °SR	16	20.5	29	38	50
		1.51	1.51	1.51	1.52	1.53	1.55	Consistency %	1.53	1.51	1.5	1.5	1.49
8	AS-	65	61.6	63.3	64	69	x	Substance (g)	x	62	60	58.6	61.7
	AQ	8.06	7.86	6.65	5.92	3.0	x	Bursting Index	x	2.7	5.1	6.82	7.353
	(0.2%)	80.98	79.6	77.7	62.74	31.3	x	Tensil Index	x	30.3	54.46	65.7	76.98
		30.78	31.2	32.12	30.64	14.21	x	Tearing Index	x	22.16	18.63	18.4	19.52
		3.87	3.75	3.5	3.87	2	x	Stretching %	x	2.31	3.0	3.62	4
		>2000	>2000	>2000	1872	38	x	Floding endurance	x	100	1210	>2000	>2000

Table 6. Strength properties of Cooks 13 and 14

Cook	Pulping	Unbleached Sheet					Process	Bleached Sheet				
		60	45	30	15	0	Beating Time min	0	15	30	47	
		64	51.5	36	25.3	17.6	Freeness in °SR	17.5	27.6	48.3	68	
		1.4	1.45	1.45	1.46	1.56	Consistency %	1.75	1.59	1.43	1.43	
		60	54	58.6	59.2	51	Substance (g)	51	50.3	50	51.5	
		7.9	8.23	7.44	5.82	3.31	Bursting Index	2.48	3.46	5.4	5.52	
13	AS	87.255	88.9	63.8	54.1	38	Tensile Index	25.5	51	62.1	68.7	
		16.34	17.25	18.4	25.2	21.53	Tearing Index	14.03	11.1	8.82	17.45	
		4.0	4.124	3.5	3.7	4.0	Stretch %	3.19	3.69	3.88	3.81	
		>2500	>2500	1900	1600	58	Folding endurance	10	195	335	226	
		60	45	30	15	0	Beating Time min	0	15	30	45	60
		64	50	37.0	28.5	17.5	Freeness in °SR	17	23	35	51.5	67
		1.48	1.5	1.5	1.51	1.53	Consistency %	1.75	1.58	1.58	1.58	1.52
		62.4	62.5	61.4	61.9	67.8	Substance (g)	57	50.5	51	60.4	62.6
		8.67	7.8	6.34	4.16	2.1	Bursting Index	1.7	4.23	6.8	6.1	7.27
14	AS-AQ	92.06	80.1	69.4	54.7	25.78	Tensile Index	22.5	47.2	66.48	71.55	78.04
		16.8	18.5	19.8	21.54	19.4	Tearing Index	11.52	25	17.7	17.52	15.66
		4.0	3.63	3.25	3.5	3.0	Stretching %	3.25	4.25	5.0	5.0	4.75
		>2000	>2000	>2000	1380	8	Folding endurance	10	486	>2000	>2000	>2000

washing the cooked pulps, requiring additional permanganate to oxidise the reddish colour. From the black liquor analysis, it is indicated that solid content and pH are dependent on the yield of pulp and total cooking chemical respectively.

From Table 2, it appears that the brightness of

unbleached pulp decreses upon decreasing the percentage of Na_2SO_3 as well as addition of AQ in the cooking liquor. It also indicates that AQ pulps consume less amount of chlorine and produce higher yield of bleached pulp of low copper number which is the indication of low reducing groups present in the bleached pulp.

The strength properties of the cooks 1 and 2 for both unbleached and bleached sheets are shown in Table 3. The results show that the strength properties of AS-AQ pulp are better than those of AS pulp. Table 4 shows the strength properties for the cooks 3 and 4. Here the strength properties are not improved except folding endurance due to addition of AQ. This indicates that AQ does not work at low alkali concentration (1.55% as Na_2O) although the sulphite dose is higher in comparison to cooks 1 and 2. Table 5 shows the effect on strength properties of different doses of AQ at higher alkaline (2.33%) condition. It indicates that there is no appreciable improvement in strength properties except tensile index, in the case of 0.05% and 0.1% AQ but on 0.2% AQ addition, the strength properties are better except folding endurance. Table 6 shows the strength properties for the cooks 13 and 14 where total cooking chemicals have been further increased by increasing the amount of sulphite and slightly decreasing the alkali dose (1.94%). At this alkaline condition, AQ is effective in increasing the strength properties of pulp.

CONCLUSION

In the mild alkali sulphite process, the activity of AQ depends on alkali present in the cooking liquor. We find that AQ has no effect in respect of yield and strength properties at 1.55% (as Na_2O) alkali concentration but at 2.33% alkali concentration, better delignification with higher strength properties have been observed although there is no improvement in pulp yield. However, at 3.87% (as Na_2O) alkali, AQ is most effective for giving higher yield and superior delignification than that of AS pulp. Another effect found is that bleached pulp yield is higher with lower chlorine consumption for AS-AQ pulp than that of AS pulp. One of the important features of AS-AQ pulp is to produce strong pulp without odour and its low requirement of alkali.

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