Bagasse Semichemical Pulp by Alkali Treatment

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ABSTRACT

Semichemical pulps from depithed bagasse fibres were produced using an alkaline pretreatment at mild temperature (100°C) followed by mechanical defiberation and refining. By using a chemical charge of 10% NaOH, liquor ratio 6:1, pulping temperature 90°C, pulping time 180 minutes and fibrillation time 12 minutes, the most favourable yield to permanganate number relationship with good strength properties is observed.

INTRODUCTION:

Non-wood fibres are suited for the smaller mills required for the limited markets in developing countries. The productive capacity of paper making pulp from fibres other than those of wood has increased dramatically to above 10% of the total(1). These fibers play a highly significant role in the economy of some developing countries where wood supply is limited or costly. Pulping of bagasse chemically and mechanically has been the subject of investigations for making different varieties of paper(2-4). As a rough estimate on a worldwide basis, there is about 1.2 to 1.3 tons of bagasse (moisture - free basis) produced per ton of sugar produced.

Although several papers about mechanical pulping of sugar cane bagasse have been published(5) very little is known about the extent to which the established high yield pulping technology can be applied to non-wood plant fibres(6).

Bagasse chemi-mechanical pulping processes have been developed(7-8). Experience shows that a chemi-mechanical pulping process relies on successful chemical pretreatment of the bagasse. It is well known that chemical treatments play a prominent role in improving the efficiency of mechanical pulping and the strength properties of the resulting pulp[9]. The pretreatment step results not only in a softening of the fibre structure, so as facilitate refining, save energy and improve strength properties, but also provides the possibility of better bleachability in the final bleaching step[10].

One of the commonly used chemicals in the treatment of bagasse prior to refining is sodium hydroxide. In studies of pretreatment and pulping of bagasse CMP, it has previously been reported (11-13) that such alkaline treatment can lead to drastic reductions in refining energy and much improved strength. However sodium hydroxide pretreatment causes deterioration of some optical properties of the pulp, owing to its darkening effect. This negative effect is substantially intensified at increasing chemical additions and treatment temperatures, The results suggest that the darkening of bagasse may be minimized if the conditions of the alkaline treatment re properly chosen.

This study aims to prepare a semichemical bagasse pulps (SCP). The effect of sodium hydroxide pretreatment on fibrillation rates, yield, brightness, pulp characteristics and paper properties were investigated.

EXPERIMENTAL:

Raw Materials Used

Depithed bagasse, supplied by Edfo mill, Egypt were used in this study. Crushing and screening using 40/60 mesh screens were used to prepare the bagasse samples. Only a portion above 60-mesh screen was used to make all chemical analysis, according to standard methods. The pulp and bagasse samples were conditioned in polythene bags for 48 hours, and then their moisture contents were determined.

The analyses of the bagasse and the standard methods of bagasse and pulp analysis are compiled in Table-1.

Water retention value (W.R.V.) of the pulp was determined by Jayme method (14). The degrees of polymerization (D.P.) were calculated from the viscosity values (15).

Table-1: Analyses of bagasse from Edfo mill in Egypt.

Property	Whole bagasse	Depithed bagasse	Method
Moisture content	8.0	8.0	SCAN-3:78
Extractable in Alcohol-benzene	2.6	2.1	Tappi T 204 om-88
Extractable in Hot water	3.7	3.3	Tappi T 207 om-88
Extractable in Cold water	2.0	1.3	Tappi T 207 om-88
Extractable in 1% NaOH	25	20	Tappi T 212 om-88
Ash content	2.2	1.4	Tappi T211 om-86
Lignin	20	19	Tappi T 222 om-88
Holocellulose	77	80	Tappi T 9 wd-75
α- cellulose	43	47	Tappi T 203 om-88
Pentosan	28	24	Tappi T 223 om-84
Permanganate No.	--	--	Tappi T 214 wd-76
Viscosity	--	--	SCAN-CM 15:88

Bagasse (SCP) with Sodium Hydroxide Pretreatment

The depithed bagasse fibres were first pretreated with different charges of sodium hydroxide varied between 2 and 10% based on bagasse in a thermostatic bath at 40-90°C. The liquor ratio was 6:1. The treatment time varied between 1, 2 and 3 hour. After chemical treatment, fibrillation and refining of the samples were carried in a laboratory blender. Hot water (95°C) could be added to the blender to adjust the refining stock consistency which was kept at 2%, and the mixing time was 3 min. Black liquors were analyzed according to TAPPI standard methods. The pulp samples were disintegrated according to SCAN-M 2:64, and screened through a Somerville reject analyzer (slit width 0.16 mm) at a constant water flow of 8 lt/min., for 20 min. The resulting pulp suspension was collected and washed with water and the pulp yield was determined. The collected fibre material was then used for analysis and to make paper hand sheets. Paper property was analysed according to SCAN-M 8:76. The properties of different pulps were compared at constant pulp freeness of 40 CSF (Canadian standard freeness according to SCAN-M 4:65).

Beating and Disintegration

16 gram of pulp in small pieces were soaked in water for 24 hours, then beaten in a Jokro -Mill beater. The beating process was done at 6% pulp consistency and the speed of the beater was 150 rpm for different time intervals. At the end of the beating, the stock was diluted with water to 2000 ml and disintegrated for 2 minutes at 3500 rpm. Then the degree of the Schopper Regular (pulp freeness) was determined.

Sheet Formation

The paper sheets were prepared according to the S.C.A. Standard using the model S.C.A. sheet former (AB Lorentzen and Wettre.). In this apparatus a sheet of 165 mm diameter (214 cm surface area) was formed. The weight of oven - dry pulp used for every sheet was about 1.43 g. After sheet formation, the sheet was pressed for 4 minutes (at 5 Kg/cm^2) using a hydraulic press. Drying of the test sheets was made with the help of a rotating cylinder drum at 120°C, the sheets were then placed for conditioning at 65% relative humidity and temperature ranging from 18 to 20°C.

Physical Tests of Paper Handsheets

After conditioning, the hand sheet papers were weighted and then they were divided into suitable pieces for the physical tests. In accordance with the standard methods, the bursting strength, tensile strength and the basis weights of the sheets were measured.

RESULTS AND DISCUSSSION:

Analysis of Raw Materials

The approximate composition of dry bagasse including the ash is 46.5% carbon, 6.5% hydrogen and 46% oxygen. The compositions of the depithed bagasse used in this study are shown in Table-1.

Semichemical pulping of Bagasse (SCP):

The aim of this study was to find the optimum pulping conditions like alkali charge, cooking temperature, cooking time, liquor to bagasse ratio, and fibrillation time to produce semichemical pulp (SCP) from bagasse with satisfactory properties.

Effect of Temperature:

In order to evaluate the effect of temperature on NaOH pulping of bagasse the other pulping conditions like alkali charge, liquor ratio, cooking time, and fibrillation time were held constant as 10%, 6:1, 60 minutes, and 3 minutes, respectively, whereas, cooking temperature were varied from 40 to 90°C. The total pulp yield, screened yield, residual alkali, permanganate number, physical and chemical properties of the produced pulps have been investigated and the results are reported in Table-2 and Fig.-1.

From Fig.-1 it can be concluded that increasing the cooking temperature from 40 to 90°C decreases the total yield from 81.6 to 72.4% due to increased dissolution of lignin and pentosan and may be some degraded cellulose. Screened yield increased with increasing temperature from 54.8% at 40°C to 69.5% at 90°C, due to noticeable softening of lignin and consequently more defiberation of bagasse fibres at higher temperature. Table 2 shows that residual alkali decreased with increasing the cooking temperature. Pronounced decrease in permanganate number from 19.1 to 14.8 was noticed. The degree of polymerization (D.P.) increased with increasing cooking temperature at higher temperature.

Strength Properties of Pulp

Fig.-2 shows that both tear factor and the breaking length increased by increasing temperature and reaches upto 111.3 and 5634 m, at 90°C, respectively. By using cooking temperature at 90°C the best pulping results can be obtained with respect to yield, rejects content and physical properties of paper sheets.

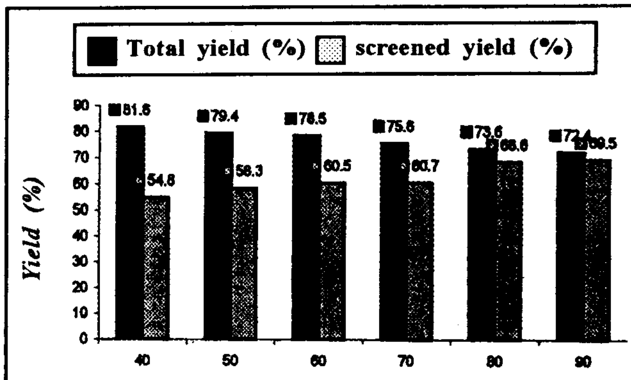

Figure 1 : Effect of cooking temperature on total and screened yield during alkali SCP of bagasse.

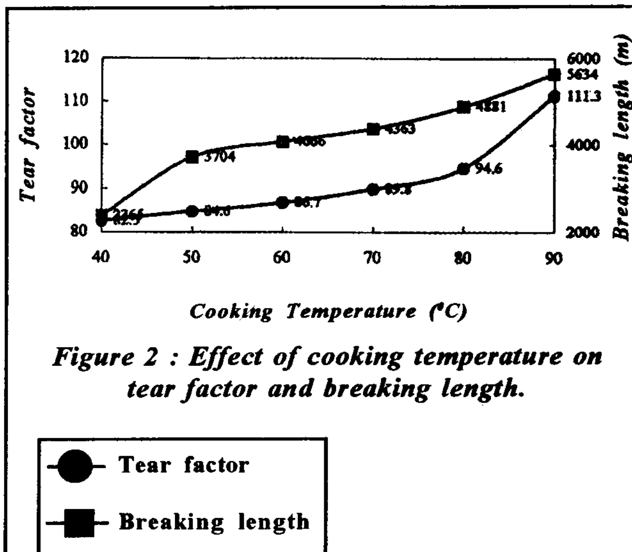

Figure 2 : Effect of cooking temperature on tear factor and breaking length.

TABLE-2
Effect of temperature on NaOH pulping of bagasse

Sample No.	Temp. (°C)	Residual alkali (g/l)	Residual alkali (%)	Permeng. No.	WRV (%)	Pentosan (%)	D.P.	Density (g/cm³)
1	40	5.97	35.8	19.1	207	19.1	492	0.400
2	50	4.75	28.5	18.6	193	18.8	502	0.411
3	60	3.95	23.7	18.2	190	18.7	541	0.415
4	70	3.10	18.6	16.7	185	18.1	603	0.427
5	80	1.62	9.72	15.6	183	17.6	691	0.466
6	90	1.43	8.58	14.8	180	14.8	783	0.517

10% NaOH, L.R 6:1, 60 minutes pulping time and 3 minutes fibrillation time

TABLE-3

Effect of NaOH concentration at different temperatures on NaOH pulping of bagasse.

Sample N.	NaOH (%)	Total Yield (%)	Screened Yield (%)	Residual alkali (g/l)	Residual alkali (%)	Perme-nganate No.	WRV (%)	Pentosan (%)	D.P.	Tear factor	Breaking length (m)	Density (g/cm³)
						at 90°C						
10	6	81.5	53.3	0.82	8.20	15.9	252	17.5	488	84.8	3399	0.414
9	8	77.3	63.4	1.22	9.15	15.2	203	15.4	666	91.4	4727	0.439
6	10	72.4	69.5	1.43	8.58	14.8	187	14.8	783	111	5634	0.517
						at 80°C						
8	8	78.5	59.6	1.5	11.3	16.2	203	17.6	592	78.6	4596	0.424
5	10	73.6	68.6	1.62	9.72	15.6	183	16.2	691	94.6	4881	0.466
						at 70°C						
7	8	79.5	55.4	2.8	21	17.0	205	18.1	512	77.2	4099	0.398
4	10	75.6	66.7	3.1	18.6	16.7	185	17.0	603	89.8	4363	0.427

L.R. 6:!, pulping time 60 min., fibrillation time 3 min.

Effect to NaOH concentration at Different Temperatures

In order to evaluate the effect of NaOH concentration on soda pulping of bagásse at diferent temperatures ranging from 70-90°C. The pulping conditions like liquor ratio, cooking time and fibrillation time were held constant as 6:1,60 min., and 3 min., respectively whereas concentration of NaOH were varied from 6 to 10% based on dry weight of depithed bagasse, and the results were reported in Table-3.

From the Table, it is concluded that total yield decreases with increasing NaOH concentration at different temperature due to increasing the dissolution of lignin and pentosan. Screened yield increases due to more defiberation of bagasse fibre at higher concentration of NaOH and also the rejects decreased. The residual alkali %, pentosan % and permanganate number decreases by increasing NaOH concentration.

Strength Properties of Pulp

From the results in Table-3 it is noticed that the W.R.V. decreases by increasing concentration of NaOH which is due to the dissolution of pentosan. The increase in D.P. at higher concentration of NaOH refers to the dissolution of pentoses and smaller degraded cellulose fragments. The strength properties of semichemical pulp depend on the severity of the chemical treatment. The strength properties of the pulp expressed as breaking length and tear factor increased with increasing sodium hydroxide concentration in the pulping liquor. The breaking length increases by increasing concentration of NaOH, till it reaches to 5634 m. at 90°C and 10% NaOH. Tear factor also has the same trend; it increases by increasing temperature, and concentration of NaOH, till it reaches to 111% at 90°C and 10% NaOH.

From the above results it can be concluded that by using a cooking temperature of 90°C and a 10% NaOH concentration, based on dry bagasse, the best pulping results can be obtained with respect to screened yield, and physical properties of paper sheets.

Effect of Pulping time

In order to evaluate the effect of pulping time on NaOH (SCP) of bagasse the pulping conditions like alkali charge, liquor ratio, cooking temperature and fibrillation time were held constant at 10% 6:1 60°C and 3 min, respectively, whereas, pulping time was varied from 60 to 360 min.

Table-4 summarizes the chemical and physical properties of NaOH (SCP) of bagasse at different pulping time. From the Table it is noticed that the total yield decreases by increasing the pulping time, and the reject decreases. The residual alkali decreases by increasing the pulping time. Fig.-3 shows that the permanganate number decreases from 18.2 at 60 min. to 14.1 at 360 minutes, the D.P. also increases by increasing pulping time. Screened yield increases by increasing pulping time, it varied from 60.5% at 60 min., to 65.5% at 360 minutes, i.e., improvement in the delignification process.

Strength Properties of Pulp

From Table-4 it is clear that the W.R.V. is slightly

TABLE-4

Effect of cooking time on NaOH pulping of bagasse

Sample No.	Cooking time (min)	Total yield (%)	Residual alkali (g/l)	Residual alkali (%)	WRV (%)	Pentosan (%)	Breaking length (m)	Density (g/cm^3)
3	60	78.5	3.95	23.7	190	18.7	4066	0.415
11	120	77.7	3.66	22.0	186	17.7	4534	0.432
12	180	75	2.95	17.7	185	16.6	4807	0.463
13	240	71	2.45	14.7	190	15.3	5263	0.494
14	360	69.2	2.17	13.0	184	14.4	5466	0.531

10% NaOH, L.R 6:1, 60 °C min., fibrillation time

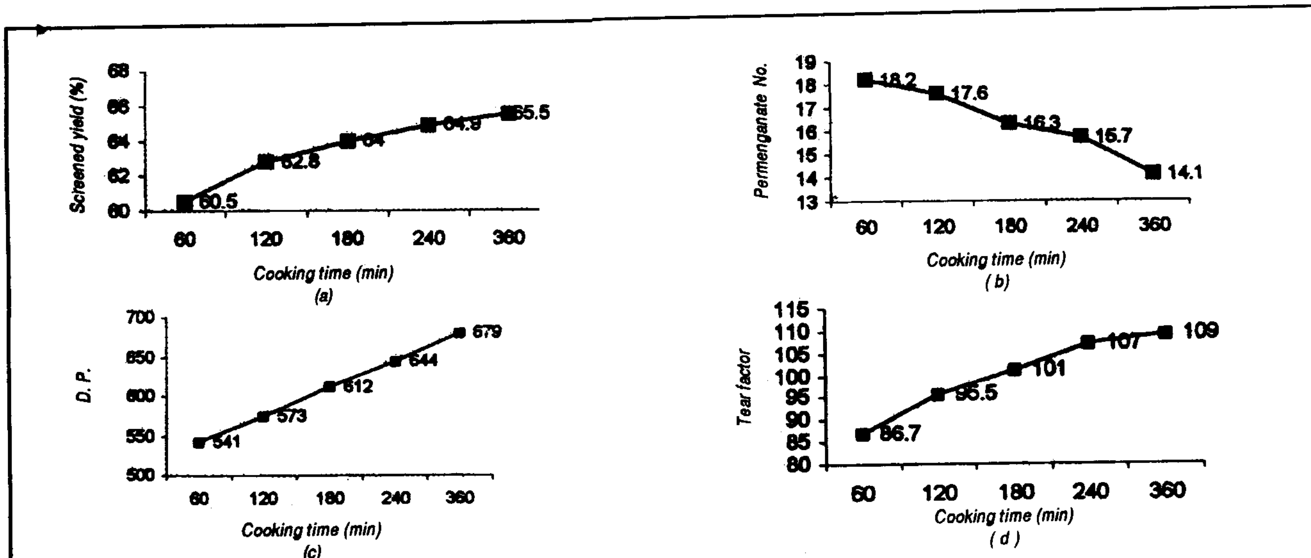

Figure 3 : Effect of cooking time on pulp and paper properties.

affected by increasing pulping time. The breaking length increases from 4066 to 5466 m by increasing pulping time from 60 to 360 min., the tear factors also have the same trend (Fig.-3) it varied from 86.7 to 109 at pulping time 60 and 360 min., respectively. From the above results it can be concluded that by using a longer pulping time (240-360min.) best pulping results can be obtained with respect to screened yield, chemical and physical properties of pulps.

Effect of Fibrillation Time

In order to evaluate the effect of fibrillation time on fibre separation of bagasse treated with NaOH, the pulping conditions like alkali charge, liquor ratio, cooking time were held constant as 10%, 6:1, 80 C and 120 min, respectively, whereas fibrillation time were varied from 3 to 12 min.

Table-5 shows the effect of fibrillation time on the total yeild, screened yield, chemical and physical properties of alkali semichemical pulping (SCP) of bagasse. From these results it can be noticed that the total yield is slightly affected by increasing the fibrillation time. The screened yield (Fig.-4) increases progressively by increasing fibrillation time due to more defiberation of treated bagasse fiber under the mechanical action, it increases from 60.5% at 3 min. to 69.1% at 12 min. fibrillation time. The permanganate number and pentosan content slightly decrease with increasing the fibrillation time. The D.P. slightly increases with increasing the fibrillation time. These results indicated the importance of the mechanical action in this kind of pulping process in which partial dissolution of lignin and carbohydrates gives better swelling. This makes the subsequent refining more effective and enhances the strength properties.

Strength Properties of Pulp

Table-5 shows that W.R.V. increases by

TABLE-5 Effect of fibrillation time on NaOH pulping of bagasse								
Sample No.	Fibrillation time (min)	Total yield (%)	Residual alkali (g/l)	Residual alkali (%)	Permeng No.	WRV (%)	Pentosan (%)	D.P.
15	3	71.2	1.32	7.92	14.6	187	16.5	726
16	6	70.5	1.32	7.92	14.7	190	16.4	733
17	8	70.2	1.32	7.92	14.3	190	16.1	742
18	12	69.8	1.32	7.92	14.5	217	16.1	745

10% NaOH, L.R 6:1, pulping time 120 min., temp., 80°C

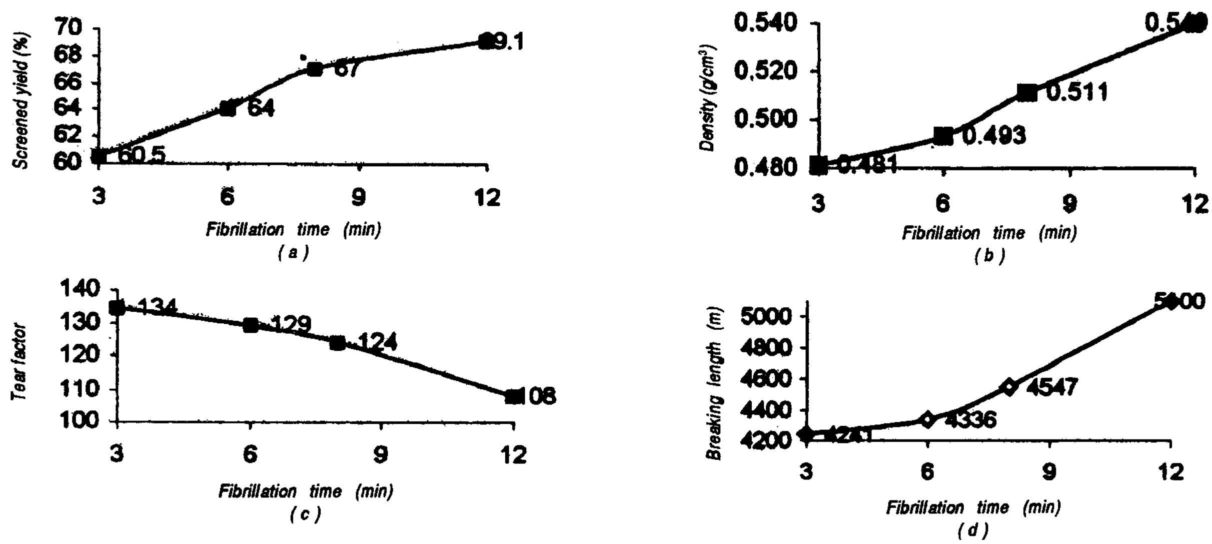

Figure 4 : Effect of fibrillation time on pulp and paper properties.

increasing fibrillation time, it is based on the effect of the mechanical action on fibre separation and increases of the fibre surface. Fig.-4 shows that the breaking length increases by increasing fibrillation time, it reaches to 5100 m at 12 min., fibrillation time from initial value 4241 m at 3 min. Tear factor shows a significant decrease with increasing in the fibrillation time. The value of tear factor decreased to 108 at 12 min. Fibrillation time from the initial value 134 at 3 min. fibrillation time. This is due to the increase of fines as indicated by increasing density, since the number of fibres with in the sheet is of great importance for the tearing strength. From the above results it can be concluded that the best pulping results can be obtained by using a fibrillation time for 12 min.

Effect of Liquor Ratio (LR)

In order to evaluate the effect of liquor to bagasse ratio (LR) on NaOH pulping of bagasse the pulping conditions like alkali charge, cooking time, cooking temperature and fibrillation time were held constant as 10%, 120 min., 80°C and 3 min, respectively. Liquor ratios (LR) were varied from 4:1 to 8:1.

Table-6 shows the effect of liquor to bagasse ratio on the total yield, chemical and physical properties of alkali SCP of bagasse. From these results it can be noticed that the total yield is slightly affected by liquor ratio.

The screened yield (Fig.-5) increases by increasing liquor ratio, till it reaches to 60.5% at liquor ratio 6:1 and with further increasing in liquor ratio, screened yield value decreased to 47% at liquor ratio 8:1. This is due to the effect of dilution of pulping liquor when using high liquor ratio. Residual alkali decreases by increasing liquor ratio. Permanganate number and pentosan content slightly decreased with increasing liquor ratio (LR), till it reaches to 14.6 and 16.5% respectively, at liquor ratio 6:1. With further increase in liquor ratio, permanganate number and

TABLE-6

Effect of Liquor ratio (LR) on NaOH pulping of bagasse

Sample No.	LR	Total yield (%)	Residual alkali (g/l)	Residual alkali (%)	Permeng. No.	Pentosam (%)	D.P.	Density (g/cm³)
19	4:1	72.5	3.95	15.8	15.1	17.1	697	0.428
20	5:1	72.0	2.78	13.9	14.8	16.8	705	0.448
15	6:1	71.2	1.32	7.92	14.6	16.5	726	0.481
21	7:1	72.5	1.08	7.56	14.8	16.8	734	0.501
22	8:1	73	0.9	7.2	14.9	16.6	732	0.509

10% NaOH, pulping time 120 min., temp., 80 °C, fibrillation time 3 min.

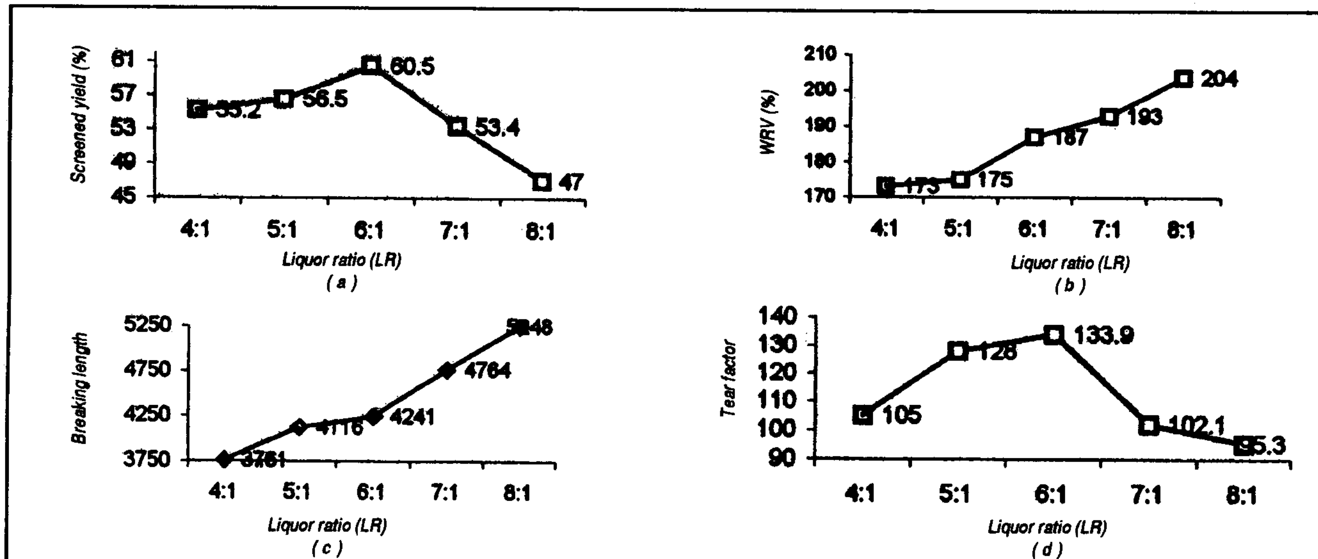

Figure 5 : Effect of Liquor ratio on pulp and paper properties.

pentosan content were increased, this may be due to decrease in the chemical action and consequently decrease the delignification effect. The D.P. value increases by increasing liquor ratio.

Strength Properties of Pulp

Fig.-5 shows that W.R.V. increases by increasing liquor ratio. Tear factor increases with increasing liquor ratio, till it reaches to 133.9 at liquor rate 6:1 With further increase in liquor ratio, it decreased to the value 95.3 at liquor ratio 8:1. The breaking length and the density were increased progressively by increasing liquor ratio up to 8:1.

From the above results we could conclude that best pulping results can be obtained by using liquor ratio 6:1 with respect to screened yield, chemical and physical properties of pulps.

Brightness Values

The brightness values of three selected samples were compared and listed in Table 7.

The brightness of the bagasse pulps produced with sodium hydroxide treatments decreased with increasing sodium hydroxide concentration. It has brightness values of 36 and 32% ISO by using 8 and 10% sodium hydroxide, respectively. Increasing of cooking temperature from 60 to 90°C improves the brightness values from 27 to 32 ISO percent.

Hydrogen peroxide with NaOH pretreatment of bagasse during chemimechanical pulping can significantly improve the brightness of the produced pulp (16,17). It was found that (16) the addition of 4% H_2O_2 during treatment with 8% NaOH at 60°C for 120 minutes increased the brightness value to 38% . Using of EDTA, DTPA and 1,10- phenanthroline as additives during alkaline H_2O_2 pulping causes and increase on the brightness values from 38 to 43, 45 and 42 ISO%, respectively. For the bleaching of the high yield pulp the sodium dithionite and hydrogen peroxide are the main processes used alone or in combination in single or two stage process to obtain a final brightness of 50-70% (13,18).

TABLE-7
Brightness Values of bagasse pulp

Sample No	NaOH (%)	Pulping condition Time (min)	Temperature (°C)	ISO Brightness (%)
9	8	60	90	36
6	10	60	90	32
11	10	120	60	27

Pulp Utilization

From the results it is clear that the obtained pulp have a good strength properties. Breaking length varied from 4000 to 5500 m and the tear factor varied from 85 to 110. The pulp properties are comparable with that of Cuba-9 chemi-mechanical (CMP) bagasse pulp which successfully used for newsprint production using 80% bagasse CMP with 10% semi-bleached kraft pulp (SBK) and 10% newspaper waste (8). A furnish of 70% bagasse CMP and 30% SBK with filler and sizing gave a good qualities of offset printing paper for textbook (8). Comparable properties to conventional newsprint specification could be reached when the bagasse CTMP was mixed with 15% softwood bleached kraft pulp (19). CMP from bagasse can be used for newsprint paper and similar for the manufacture of writing and printing papers, for wrapping paper and in a high proportion in the nappy manufacture (13).

CONCLUSION

In a high yield semichemical pulping process (SCP), the swelling and softening of the fiber material prior to refining is essential to increase fiber flexibility, prevents excessive fibre cutting during mechanical treatment, and promotes the formation of a pulp with a good paper making. Soda pulping was carried out using 6-10% sodium hydroxide, based on o.d bagasse for 1-6 hr., at 40-90 C, liquor ratio 4:1 -8:1, fibrillation time 3-12 min., and the pulp obtained. The screened yield of the mild soda pulping of bagasse ranged between 69.5 to 72% compared with 50% for kraft bagasse pulp. The strength properties of the prepared semichemical pulp are comparable with other chemical pulping.

In conclusion the following optimum conditions are recommended : NaOH (based on o.d. bagasse) 10%, temperature 90°C, treatment time 3 hr, liquor ratio 5:1 - 6:1 and fibrillation time 12 min.

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