Bagasse Semichemical Pulp by Alkaline Hydrogen Peroxide Treatment

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ABSTRACT

High yield semichemical pulps from depithed bagasse fibres were produced using alkaline hydrogen peroxide treatment. Increasing hydrogen peroxide addition at constant alkali concentration during bagasse pulping accelerates pulp delignification and improves the brightness properties of the semichemical pulp (SCP) produced but decreases the strength properties and increases the required fibrillation time. By using 8% of NaOH with 4% of H_2O_2, liquor ratio 6:1, pulping time of 180 min. pulping temperature 80°C and fibrillation time of 5 min., pulp with high yield (72%) with satisfactory strength and optical properties was obtained. Addition of EDTA or DTPA as chelating agent and 1,10 phenanthroline as catalyst during the alkaline hydrogen peroxide pulping of bagasse accelerates pulp delignification, increases the pulp brightness and improves strength properties.

INTRODUCTION

There is growing concern about both the availability of wood and the environmental effects resulting from pulping and bleaching of chemical pulps. High yield pulps have few environmental issues associated with their manufacture, as no or little chemicals are used. Additionally, the high yield results in roughly twice the pulp produced per tonne of raw material as compared to chemical pulps.

Thermo-mechanical pulping (TMP) process was applied (1) to bagasse for economic production of high yield pulp with pollution abatement for newsprint. TMP of bagasse mixture with 20-30% softwood bleached kraft pulp attains the newsprint grade level. Hydrogen peroxide has been used as an effective lignin-preserving bleaching agent successfully in pretreatment of wood chips, together with sodium hydroxide, to suppress the formation of chromophoric structures during alkali pretreatment and to improve the bleachability of the pulp produced (2). Promising results in brightness improvement of bagasse after applying hydrogen peroxide in a NaOH /H_2O_2 co-impregnation system were also obtained in a preliminary study (3). Hydrogen peroxide addition during alkaline pretreatment of bagasse reduces the formation of chromophoric structures and improves the bleachability of the pulp produced.

It is well known that chelating agents play an important role in the peroxide brightening of mechanical pulps due to the stabilization of hydrogen peroxide solution (4). Also, peroxide - alkaline delignification catalyst; 1,10 - phenanthroline (subsequently simply phenanthroline), proposed for alkaline oxygen pulping is the most effective of all known catalysts (5). Phenanthroline added into the cooking liquor, penetrates through wood tissues by diffusion and coordinates with variable valence metals, bound with wood complexes where it acts as ligand and metal acts as central ion.

This study aims to produce high yield semichemical bagasse pulp (SCP) by alkaline hydrogen peroxide delignification. Effect of additives such as 1,10-phenanthroline, EDTA (ethylene diamine tetra acetic acid) and DTPA (diethylene triamine penta acetic acid) were studied with respect to delignification, yield, brightness and properties of pulp and paper sheets produced.

EXPERIMENTAL

The depithed bagasse described in previous work (6) was used in this study. It has the following composition: ash 1%, lignin 19%, cold water extractives 1.2%, hot water extractives 3.3%, NaOH solution extractives 22%, alcohol - benzene extractives 2.4%, alpha-cellulose 45%, pentosan 23%, and holocellulose 61%.

In this method, depithed bagasse was treated with different charges of hydrogen peroxide and sodium hydroxide in a water thermostatic bath at 40 and 60°C. The liquor ratio was retained at 6:1 and the treatment times varied between 1,2 and 4 hours. After chemical pretreatment, the samples were subjected with its black liquor to fibrillation for 5 minutes in a laboratory blender (3500 rpm) under atmospheric conditions. The refining stock consistency in the blender was adjusted to 2% by using hot water (95°C).

Black liquor and pulp were analyzed according to standard methods (6). Hand sheets were prepared at constant pulp freeness of 40° (CSF) and tested as described elsewhere (6).

RESULTS AND DISCUSSION

Alkaline hydorgen peroxide semichemical pulping (SCP) of bagasse.

In this study, we explored the optimum pulping parameters like total NaOH concentration, H_2O_2 concentration, cooking temperature, pulping time, liquor to bagasse ratio and fibrillation time to produce high yield semichemical bagasse pulp with good chemical, physical and optical properties and also with lower energy demand and with minimum environmental impact. The utilization of alkaline H_2O_2 in pulp treatment is accompanied by both lignin removal caused by oxidative ring opening of aromatic rings to form carboxylic acid groups and lignin bleaching as a result of peroxide anions attack on chromophoric groups such as conjugated carbonyl structures (7).

Effect of temperature

To evaluate the effect of temperature on NaOH /H_2O_2 semichemical pulping of bagasse the pulping conditions like alkali charge, hydrogen peroxide concentration, liquor ratio, pulping time and fibrillation time were held constant as 8%, 4%, 6:1, 180 min and 5 min respectively. The cooking temperature was varied from 30 to 80°C. The results shown in Table 1 clearly indicate that the total yield decreases by increasing cooking temperature due to increased dissolution of water soluble materials and may be some degraded cellulose, while the screened yield (Fig.1) increases by increasing of temperature, till it reaches to 72% at 80°C. The residual NaOH and H_2O_2 decrease with increasing temperature. Increase of the temperature decreases the permanganate number from 18.0 at 30°C to 14.8 at 80°C, i.e., delignification process is improved. The pentosan content has also the same trend. Degree of polymerization (D.P.) increases by increasing cooking temperature due to effective dissolution of soluble materials of bagasse fibre by the chemical action during the pretreatment.

The results shown in Table 1 clearly indicate that the W.R.V. decreases with increasing cooking temperature. This is attributed to dissolution of the highly hydrophilic materials such as degraded cellulose and pentosan. The density of sheet increases by increasing cooking temperature. Fig.1 shows that with increasing cooking temperature from 30 to 80°C, tear factor increases from 83.4 to 139 and also the breaking length increases from 2395 m at 30°C to 3831m at 80°C. From the above results, it could be concluded that, increasing cooking temperature leads to improvements in the screened yield, D.P., tear factor and breaking length.

Effect of increasing H_2O_2

In order to evaluate the effect of H_2O_2 in NaOH/H_2O_2 ratio during semichemical pulping of bagasse, the impregnation conditions like alkali charge, liquor ratio, pulping time, pulping temperature and

Table 1. Effect of cooking temperature on NaOH/H_2O_2 pulping of bagasse

Temp. (°C)	Total Yield (%)	Residual alk. (%)	Residual H_2O_2 (%)	WRV (%)	Pentosan (%)	D.P.	Density (g/cm³)
30	96	8.3	10	253	16.4	679	0.324
40	95.5	4.13	5.4	240	15.9	752	0.333
50	95.2	3.5	5.0	233	15.5	802	0.374
60	95.0	1.8	4.7	230	15.3	877	0.381
70	92.0	1.5	3.8	226	15.0	874	0.390
80	88.0	1.1	3.0	221	14.7	890	0.398

8% NaOH, 4% H_2O_2, L.R. 6:1, pulping time 180 min., fibrillation time 5 min.

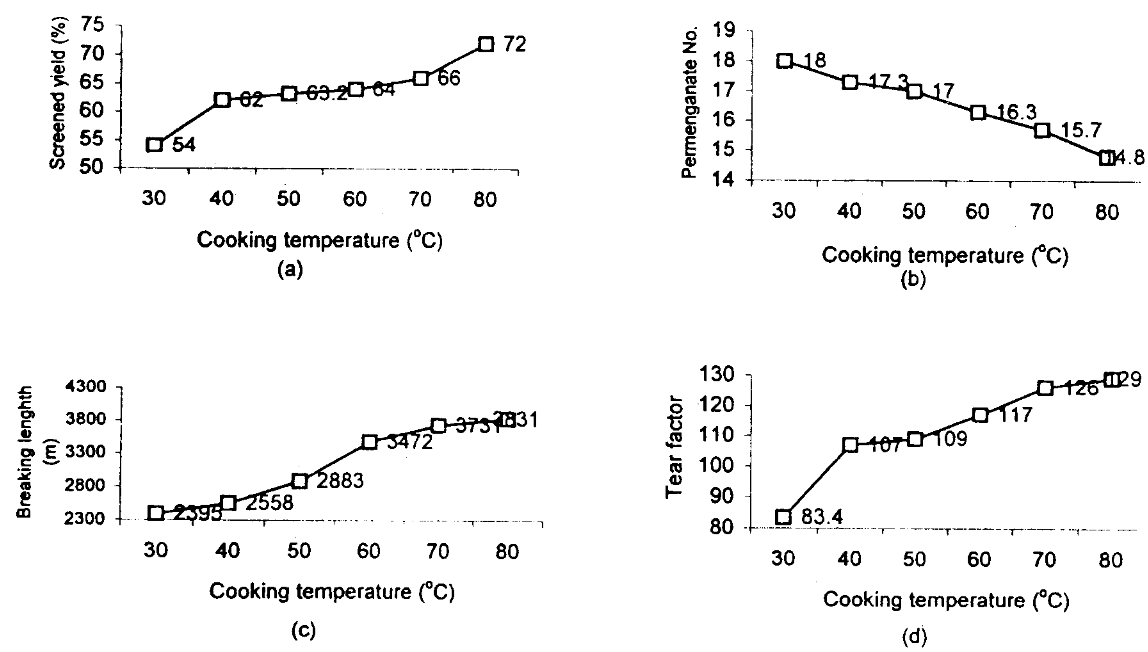

Fig.1: Effect of cooking temperature on pulp and paper properties

fibrillation time were held constant as 6%, 6:1, 180 min., 40°C and 5 min respectively; the concentration of H_2O_2 was varied from 1.5 to 6% based on bagasse raw material. Table 2 shows that total yield is marginally affected by increasing the percentage of H_2O_2 in impregnation liquor. Screened yield (Fig.2) increases by increasing the ratio of H_2O_2 to NaOH in the impregnation liquor, it reaches to 53% at 6% H_2O_2 from the initial value of 37% at 1.5% H_2O_2. The permanganate number nearly remains unchanged and the pentosan percentage increases with increasing the H_2O_2 percentage in impregnation liquor. Fig.2 shows that the degree of polymerization (D.P.) increases by increasing the percentage of H_2O_2 in impregnation liquor. These results elucidate that increasing the percentage of H_2O_2 in impregnation liquor could attain improvement in the delignification process. Table 2 shows that W.R.V decreases by increasing the percentage of H_2O_2 in cooking liquor, the decrease in W.R.V depends on the dissolution of pentosan. From Fig.2, it is clear that the tear factor increases from 58.3 to 87.7 when the percentage of H_2O_2 increases in impregnation liquor from 1.5 to 6%. Breaking length has the same trend; it reaches to 1089 m at 1.5% H_2O_2

Table 2. Effect of NaOH/H_2O_2 ratio on pulping of bagasse

NaOH (%)	H_2O_2 (%)	Total Yield (%)	Residual alkali (%)	Residual H_2O_2 (%)	Permen-ganate No.	WRV (%)	Pentosan (%)	Density (g/cm³)
6	1.5	97	1.3	10.9	18.5	247	18.9	0.267
6	2.25	96.5	1.1	8.5	18.4	239	18.2	0.272
6	3	95.7	1.1	6.6	18.3	238	17.8	0.274
6	4.5	96.0	0.06	4.7	18.6	227	16.8	0.297
6	6	96.0	0.04	4.4	18.8	223	16.1	0.307

L.R. 6:1, pulping time 180 min., temp. 40°C, fibrillation time 5 min.

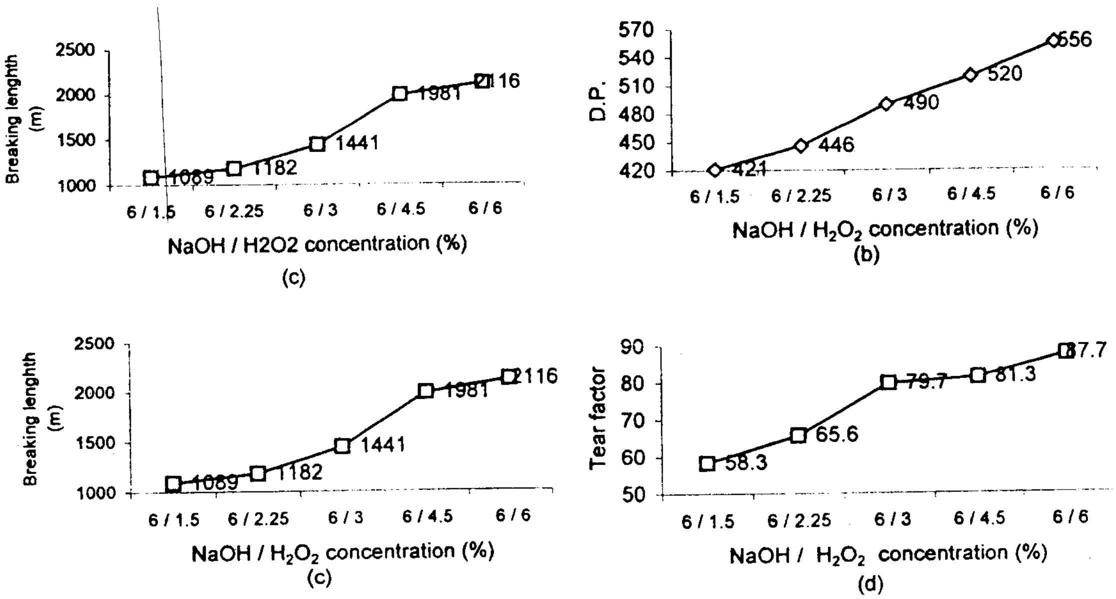

Fig.2: Effect of increasing H_2O_2 in NaOH / H_2O_2 ratio on pulp and paper properties.

and 2116 m at 6% H_2O_2. From the above results, it could be concluded that with increasing H_2O_2 in NaOH/H_2O_2 ratio, the best pulping results can be obtained with respect to screened yield, reject chemical and physical properties of pulps.

Effect of chemical concentration at different temperatures.

In order to evaluate the effect of chemical concentration at different temperatures on semichemical pulping of bagasse by NaOH/H_2O_2 process, the pulping conditions like liquor ratio, pulping time, temperature and fibrillation time were held constant as 6:1, 180 min., 40°C and 5 min respectively whereas the alkali charge was varied from 4 to 8% and the concentration of H_2O_2 from 2 to 4%. Some experiments were carried out at 60°C for comparison. In this study the ratio of sodium hydroxide to hydrogen peroxide concertration in the cooking liquor equals to 2:1 to avoid undesirable oxygen formation through peroxide decomposition, thus reducing peroxide loss and deterioration of chemical uptake (8).

Table 3. Effect of chemical concentration on NaOH/H_2O_2 pulping of bagasse

NaOH (%)	H_2O_2 (%)	Total Yield (%)	Residual alkali (%)	Residual H_2O_2 (%)	Permen-ganate No.	WRV (%)	Pentosan (%)	Density (g/cm³)
4	2	97	1.00	8.16	8.16	260	19.4	0.225
5	2.5	96.5	1.20	6.98	18.1	249	18.4	0.265
6	3	95.7	1.10	6.60	18.3	238	17.8	0.274
7	3.5	96	4.11	5.83	18.0	240	16.2	0.326
8	4	95.5	4.13	5.40	17.3	240	15.9	0.333

L.R. 6:1, pulping time 180 min., temp. 40°C, fibrillation time 5 min.

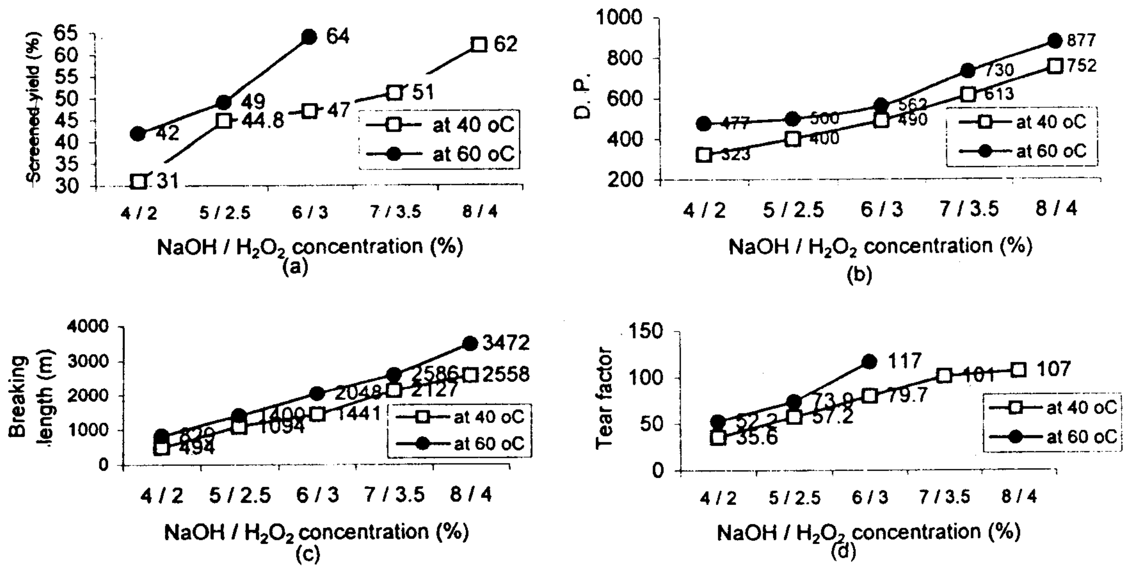

Fig.3: Effect of NaOH / H_2O_2 concentration on pulp and paper properties.

Table 3 summarizes the effect of chemical concentration on pulping of bagasse by NaOH / H_2O_2. From this Table, it could be noticed that with increasing chemical concentration the total yield slightly decreases. The screened yield Fig.3 increases from 31 to 62% by increasing the chemical concentration of NaOH/H_2O_2 from 4/2 to 8/4%, this is due to more softening of fibres and removing of lignin which causes easier separation and defibrillation of bagasse fibre. The screened yield could be improved more by using special mechanical treatment, as disk refiner, in place of a laboratory blender. The permanganate number and pentosan content were decreased, i.e., improvement in the delignification process. The D.P. (Fig.3) increases from 323 at 4/2 to 752 at 8/4% NaOH/H_2O_2.

Table 3 shows that W.R.V. decreased from 260 to 230% at 4/2, 8/4 NaOH/H_2O_2, the decreasing of W.R.V. depends on the dissolution of pentosan because pentosan is more hydrophilic than cellulose. Fig.3 illustrates the variation of tear factor by increasing NaOH/H_2O_2 concentration. It varied from 35.6 to 107 at 4/2 and 8/4% NaOH/H_2O_2 respectively. Breaking length has the same trend, since it reaches to 494 m at 4/2% (NaOH/H_2O_2) and to 2558 m at 8/4% (NaOH/H_2O_2). The density of hand sheet increases by increasing chemical concentration. From the above results and figure, it can concluded that with increasing the percentage of NaOH/H_2O_2 up to 8:4; based on o.d. bagasse, the best pulping results can be obtained, also increasing the cooking temperature from 40 to 60°C improves the pulp properties.

Effect of pulping time

In order to evaluate the effect of pulping time at different cooking temperatures on NaOH/H_2O_2 semichemical pulping of bagasse, the pulping conditions like alkali charge, H_2O_2 percentage, liquor ratio and fibrillation time were held constant as 8%, 4%, 6:1 and 5 min respectively whereas the pulping time varied from 60 to 240 min at 40 and 60°C cooking temperature. Table 4 summarizes the effect of pulping time on pulping of bagasse by NaOH/H_2O_2. From the Table, it could be noticed that with increasing the pulping time, total yield and also the rejects were decreased. This is due to the increase of lignin and pentosan dissolution and some degradation of cellulose.

Screened pulp yield Fig.4 increased from 52 to 63.8% with increase in the pulping time from 60 to 240 min at 40°C. This is due to more defibrillation of bagasse fibre at longer pulping time; and the residual alkali and H_2O_2 were decreased with increasing pulping time. The permanganate number decreases from 18.8 to 16.8 when the pulping time increases from 60 to 240 min and also the pentosan contents were

Table 4. Effect of treatment time during $NaOH/H_2O_2$ pulping of bagasse

Time (min)	Total Yield (%)	Residual alkali (%)	Residual H_2O_2 (%)	Permen-ganate No.	WRV (%)	Pentosan (%)	Density (g/cm³)
60	96.5	5.25	7.5	18.8	282	18.6	0.308
120	96	4.50	6.6	18.2	245	17.1	0.319
150	95.8	4.35	60	17.6	240	16.2	0.324
180	95.5	4.13	54	17.3	240	15.9	0.333
240	90.0	2.63	48	16.8	236	15.1	0.357

8% NaOH, 4% H_2O_2, L.R. 6:1, time 180 min., temp. 40°C, fibrillation time 5 min.

decreased from 18.6 to 15.1% i.e., improvement in the delignification process. The D.P. increases with increasing pulping time as shown in Fig.4, the initial value was 642 at 60 minutes and reaches to 805 at 240 minutes, which is due to higher pulping time where the defibrillation of bagasse fibre occurs mainly by the chemical action.

Table 4 shows that W.R.V. decreases from 282 to 236% with increasing pulping time from 60 to 240 min due to the dissolution of pentosan. Tear factor increases with increasing pulping time from 86.5 at 60 min to 117 at 240 min. Breaking length has the same trend, it varied from 2309m at 60 min to 2685 m at 240 min. The density of sheet increased from 0.308g/cm³ at 60 min to 0.457g/cm³ at 240 min. Fig. 4 illustrates the variation of screened yield, D.P., breaking length and tear factor with pulping time. From this figure, it could be concluded that the best pulping results are possibly obtained at longer pulping time and at higher temperature.

Effect of fibrillation time

In order to evaluate the effect of fibrillation time on $NaOH/H_2O_2$ semichemical pulping of bagasse, the pulping conditions like alkali charge, H_2O_2 concentration, liquor ratio, pulping time and pulping temperature were held constant as 8%, 4%, 6:1, 120 min., and 40°C respectively. The fibrillation time

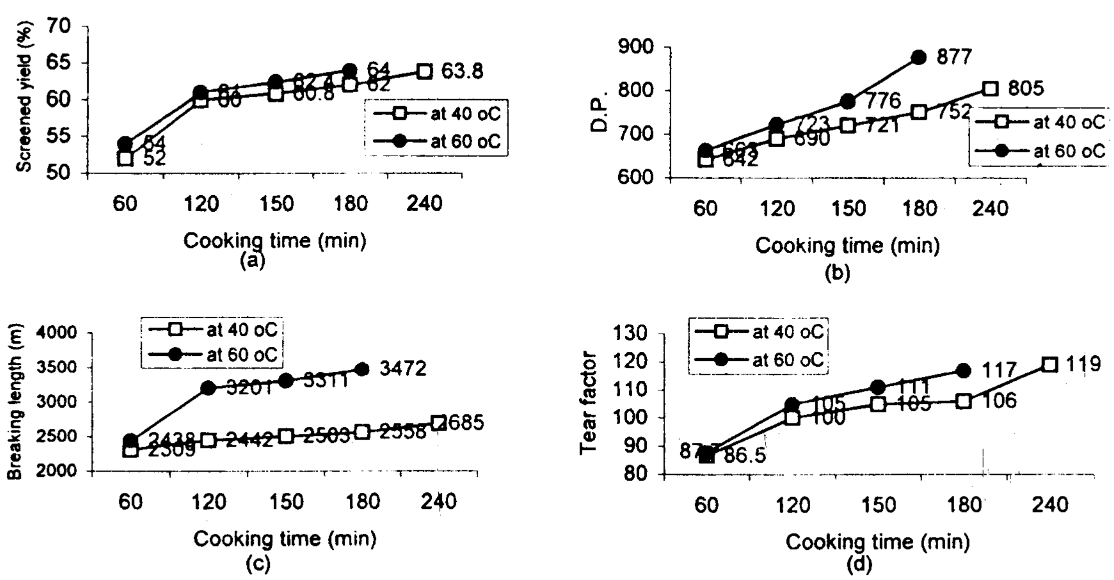

Fig.4: Effect of cooking time on pulp and paper properties

Table 5. Effect of fibrillation time on NaOH/H_2O_2 pulping of bagasse

Fibrillation time (min)	Total yield (%)	Residual alkali (%)	Residual H_2O_2 (%)	Permen-ganate No.	WRV (%)	Pentosan (%)	D.P	Tear factor	Density (g/cm³)
3	96.5	4.5	6.6	18.6	223	17.4	682	117	0.306
5	96	4.5	6.6	18.2	245	17.1	690	100	0.319
8	88	4.5	6.6	18.5	248	16.9	695	105	0.321
12	84	4.5	6.6	18.3	244	16.6	697	101	0.349

8% NaOH, 4% H_2O_2 L.R. 6:1, pulping time 120 min., temp. 40°C

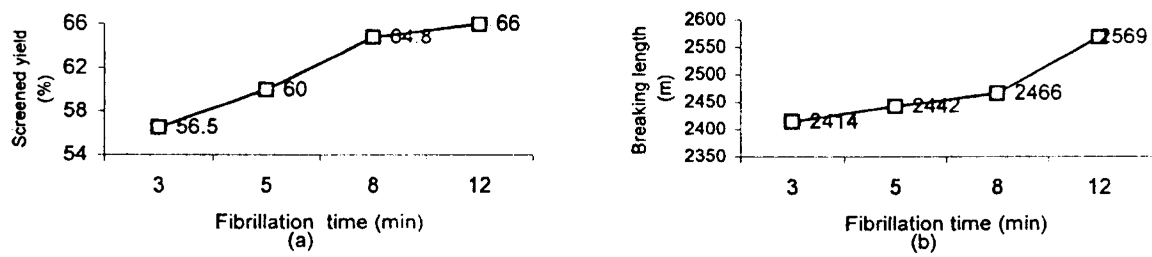

Fig.5: Effect of fibrillation time on screened yield (a) and breaking length (b).

varied from 3 to 12 minutes. Table 5 summarizes the results of fibrillation time and its effect on the pulp properties. From the table, it is noticed that the total yield decreases from 96.5 to 84% with increasing fibrillation time from 3 to 12 min., However screened yield (Fig.5) increases from 56.5 to 66% with increasing fibrillation time from 3 to 12 min. This is due to the fact that more defibrillation of bagasse fibres occurs with higher fibrillation. Increasing in fibrillation time does not affect the residual alkali and H_2O_2 values for different experiments. The permanganate number values and pentosan content of different pulps were slightly decreased by increasing fibrillation time. The degree of polymerization (D.P.) increases by increasing fibrillation time due to more dissolution of small fragments.

The hand sheet properties are presented in Table 5. Increasein in fibrillation time from 3 to 12 min, increases the W.R.V. from 223 to 244 and also breaking length (Fig.5) from 2414 to 2569m. The tear factor decreases from 117 at 3 min to 101 at 12 min fibrillation time, while the density of sheet increases with increasing fibrillation time. From all these results, it can be concluded that the increasing of fibrillation time during pulping of bagasse by the alkaline hydrogen peroxide method affects the screened pulp yield positively. There are no remarkable changes on the physical and chemical properties of pulps.

Effect of liquor ratio (LR)

In order to evaluate the effect of the liquor to bagasse ratio (LR) on NaOH/H_2O_2 semichemical pulping of bagasse, the pulping conditions like alkali charge, H_2O_2 concentration, cooking time, cooking temperature and fibrillation time were held constant as 8%, 4%, 180 min, 40°C and 5 min respectively. LR was varied from 4:1 to 8:1. Table 6 shows the effect of LR on pulping of bagasse by NaOH/H_2O_2. From the Table, it could be noticed that the total yield is nearly constant at different liquor ratios. The screened yield (Fig.6) increases from 52.2 to 62% with increasing liquor ratio from 4:1 to 6:1. Further increase in liquor ratio to 8:1, the screened yield decreases. This is due to the fact that further the LR during cooking process, diminishe, the chemical action by dilution is. Residual alkali and residual H_2O_2 decrease with increasing liquor ratio. The permanganate number and pentosan content are slightly affected by liquor ratio. It could be said that the best

Table 6. Effect of liquor ratio (LR) on $NaOH/H_2O_2$ pulping of bagasse

LR	Total yield (%)	Residual alkali (%)	Residual H_2O_2 (%)	Permen-ganate No.	WRV (%)	Pentosan (%)	D.P	Tear factor	Density (g/cm³)
4:1	0.66	3.30	4.8	17.7	218	16.1	700	90.7	0.305
5:1	0.61	3.81	5.1	17.6	228	16.3	724	104.0	0.322
6:1	0.55	4.13	5.4	17.3	240	15.9	752	106.7	0.333
7:1	0.35	3.06	6.0	18.0	243	16.1	749	88.6	0.351
8:1	0.15	1.5	6.2	18.3	258	16.2	750	85.2	0.363

8% NaOH, 4% H_2O_2 pulping time 180 min., temp. 40°C, fibrillation time 5 min.

delignification is achieved at 1:6 liquor ratio, where higher screened yield is obtained and permanganate number attains the lowest value.

Table 6 illustrates that with increasing liquor ratio from 4:1 to 8:1, the W.R.V. increases from 218 to 258% respectively. Breaking length (Fig. 6) increases from 2054 m at 4:1 LR to 2872m at 8:1 LR. Tear factor has a maximum value at LR of 6:1. The density of hand sheet and D.P. increases by increasing liquor ratio.

Effect of 1, 10 phenabthroline addition on $NaOH/H_2O_2$ pulping of bagasse

In order to evaluate the effect of adding 1,10-phenanthroline to cooking liquor of alkaline hydrogen peroxide pulping of bagasse, the selected pulping conditions like alkali charge, hydrogen peroxide concentration, cooking temperature, fibrillation time and liquor ratio were held constant as 8%, 4%, 120 min., 60°C, 5 min and 6:1 respectively whereas, 1, 10 phenanthroline charges were varied from 0.2 to 2 mmol in pulping liquor. The results obtained are reported in Table 7 and illustrated in Fig.7. It has been found that increasing the concentration of 1, 10 phenanthroline in cooking liquor from 0.2 to 1 mmol is accompanied by an increase in screened yield from 61.6 to 62.8%. Further increase in 1,10 phenanthroline concentration, decreases the pulp yield to reach 62.5% at 2 mmol 1, 10 phenanthroline. Permanganate number and pentosan content were nearly constant. The residual alkali and residual H_2O_2 decrease while D.P. slightly increases by increasing the concentration of 1,10-phenanthroline in cooking liquor.

From the results in Table 7 and Fig.7 it is noticed that the W.R.V. increases from 247 to 251% and the tear factor increases from 105.5 to 115.0 increasing the concentration of 1,10 phenanthroline from 0.2 to 1 mmol. Further increase in 1,10-phenanthroline concentration decreases the tear factor. Breaking length has also the same trend Fig.7, it increases from 3201 till it reaches to 3648 m at 1 mmol 1,10-phenanthroline

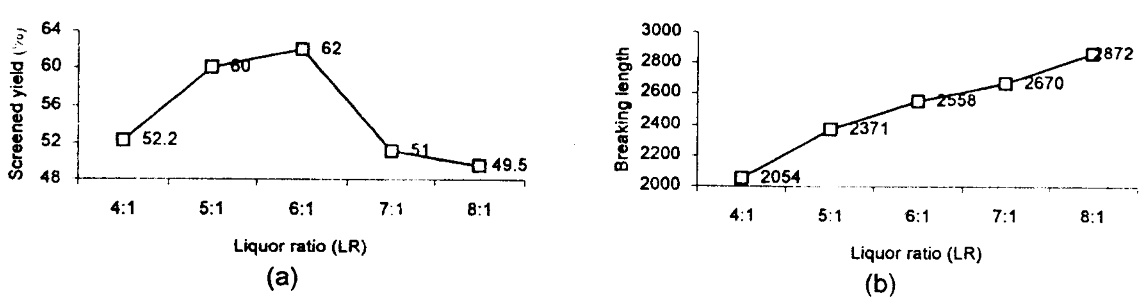

Fig.6: Effect of liquor ratio on screened yield (a) and breaking length (b).

Table 7. Effect of 1, 10 - phenanthroline addition on $NaOH/H_2O_2$ pulping of bagasse

1, 10 Ph.	Total yield mmol	Residual alkali (%)	Residual H_2O_2 (%)	Permen-ganate No.	WRV (%)	Pentosan (%)	D.P	Tear factor	Density (g/cm^3)
0	95.7	3.0	6.0	17.7	242	16.8	723	105.0	0.358
0.2	93	2.85	5.7	17.8	247	16.6	729	105.5	0.356
0.5	89.5	2.7	5.6	18.4	249	17	728	106.4	0.363
1	88	2.18	5.1	18.4	251	16.9	727	115.0	0.366
2	87.2	1.88	4.7	16.5	257	16.5	731	118.3	0.375

8% NaOH, 4% H_2O_2, LR 6:1, time 120 min., temp. 60°C, fibrillation time 5 min.

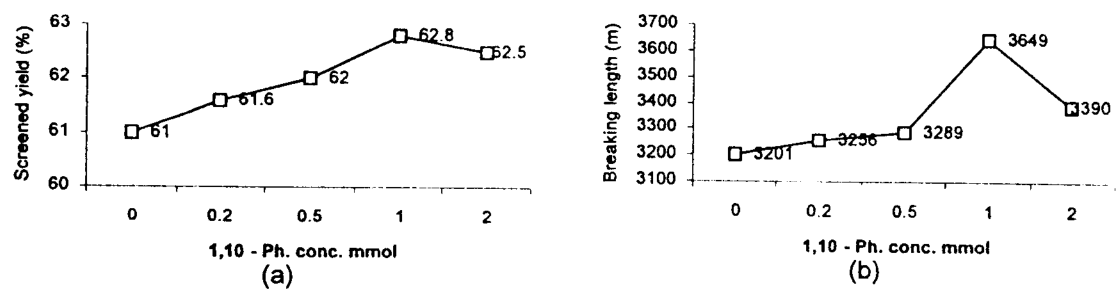

Fig.7: Effect of 1, 10- phenanthroline addition on $NaOH/H_2O_2$ pulping of bagasse.

and then decreases with increasing 1,10-phenanthroline concentration to 2 mmol. From these results, it can be concluded that the addition of 1 mmol 1,10-phenanthroline during the alkaline hydrogen peroxide pulping of bagasse is considered as the best concentration at which the efficiency of the delignification processes increases.

Effect of EDTA addition

In order to evaluate the effect of adding ethylene diamine tetra acetic acid (EDTA) as chelating agent to cooking liquor during alkaline hydrogen peroxide pulping of bagasse, the pulping condition like alkali charge, hydrogen peroxide concentration, cooking time, cooking temperature, fibrillation time and liquor ratio were held constant as 8%, 4%, 120 min., 60°C, 5 min and 6:1 respectively, whereas EDTA charge was varied from 0.1 to 0.45% based on dry weight of bagasse. The pulp yield, permanganate number, residual alkali and H_2O_2, chemical and physical properties of the pulps, have been investigated and the results are reported in Table 8 and illustrated in Fig.8. It has been found that increasing the percentage of EDTA in cooking liquor is accompanied by pronounced increase in screened yield and decrease in permanganate number, i.e. improvement in the delignification process. Further increase in EDTA percentage has contrary effect. The pentosan content decreases with increasing EDTA concentration until 0.3% addition, but with further increase in EDTA percentage, the pentosan percentage slightly increases.

Also from Table 8 the residual alkali values of different pulps are not affected by increasing the percentage of EDTA. Increasing in the percentage of EDTA relatively increases the residual H_2O_2 values of different pulps. This is due to the fact that EDTA stabilizes the hydrogen peroxide solutions by chelating the transition metal ions.

Fig.8 shows that increasing EDTA percentage in cooking liquor from 0.1 to 0.3%, is accompanied by increase in tear factor and breaking length i.e., improvement in the quality of the pulps. Further increase in EDTA percentage decreases the tear factor and breaking length. The W.R.V. decreases by increasing EDTA percentage in cooking liquor, which is due to the decrease of pentosan. The degree of polymerization and also the density increase by

Table 8. Effect of EDTA addition on NaOH / H_2O_2 pulping of bagasse

EDTA (%)	Total yield (%)	Residual alkali (%)	Residual H_2O_2 (%)	Permen-ganate No.	WRV (%)	Pentosan (%)	Density (g/cm^3)
0	95.7	3	6	17.7	242	16.8	0.358
0.1	96	3	6.95	17.4	237	16.2	0.379
0.15	93.7	3	6.9	16.8	221	15.7	0.389
0.3	92.1	3	8.3	13.9	216	15	0.395
0.45	95.5	3	7.2	14.4	216	14.6	0.396

8% NaOH, 4% H_2O_2 LR 6:1 pulping time 120 min., temp. 60°C, fibrillation time 5 min.

increasing EDTA percentage in cooking liquor. From these results, it can be concluded that the addition of 0.3% EDTA is considered as the best concentration which could be added to the peroxide alkaline pulping liquor to increase the efficiency of the delignification process.

Effect of EDTA addition

In order to evaluate the effect of adding some amount of diethylene triamine penta acetic acid (DTPA) as chelating agent in cooking liquor of alkaline hydrogen peroxide semichemical pulping of bagasse, the pulping conditions like alkali charge, hydrogen peroxide concentration, cooking temperature, cooking time, fibrillation time and liquor ratio were held constant as 8%,4%, 60°C, 120 min. 5 min., and 6:1 respectively whereas DTPA charge was varied from 0.1 to 0.45% based on dry weight of bagasse. The pulp yield, permanganate number, residual alkali and H_2O_2, chemical and physical properties of the pulps have been investigated and the results are reported in Table 9 and illustrated in Fig.9.

Table 9 shows that increasing the percentage of DTPA in cooking is accompanied by increase in screened yield and decrease in permanganate number. Further increase in EDTA percentage has detrimental effect. Fig.9 indicate that the major improvement in the pulping properties has been achieved at 0.3% DTPA addition. Also, from the results in Table 9, we notice that the residual alkali values are not affected by

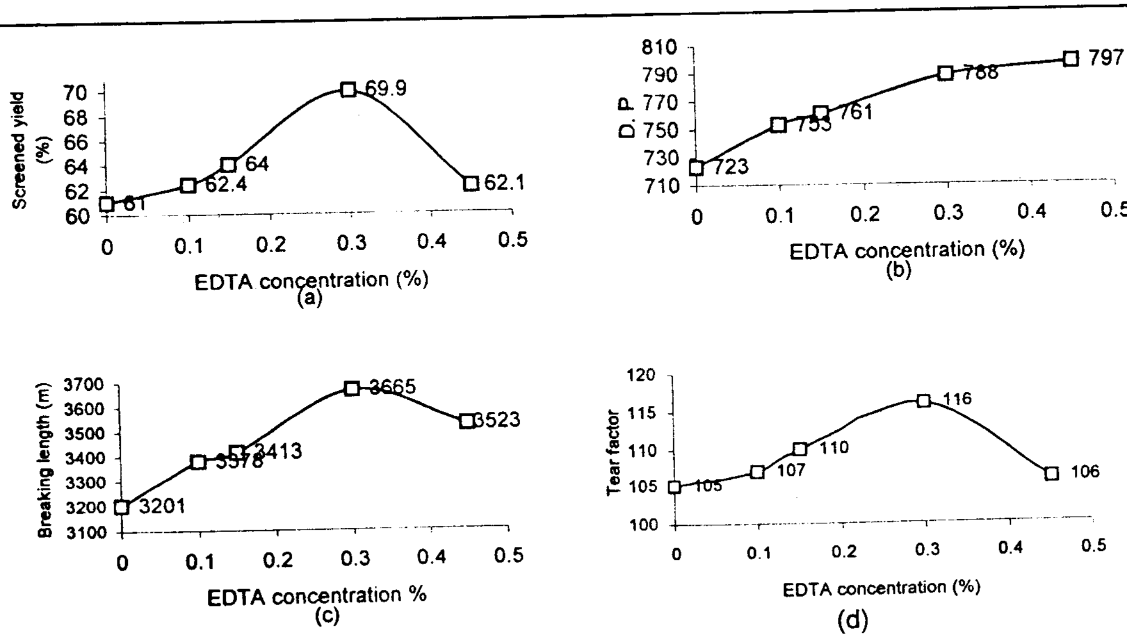

Fig.8: Effect of EDTA addition on pulp and paper properties.

Table 9. Effect of DTPA addition on NaOH / H_2O_2 pulping of bagasse

DTPA (%)	Total yield (%)	Residual alkali (%)	Residual H_2O_2 (%)	Permen-ganate No.	WRV (%)	Pentosan (%)	Density (g/cm³)
0	95.7	3	6	17.7	242	16.8	0.358
0.1	94.8	3	6.3	17.4	236	16.2	0.367
0.15	93.3	3	6.8	16.6	226	15.8	0.379
0.3	90.5	3	7.4	16.4	223	15.1	0.391
0.45	94.4	3	7.1	16.6	212	15	0.399

8% NaOH, 4% H_2O_2 LR 6:1 pulping time 120 min., temp. 60°C, fibrillation time 5 min.

increasing the percentage of DTPA, while the residual H_2O_2 values of different pulps is relatively increased by increasing DTPA percentage. This is due to DTPA which acts as peroxide decomposition inhibitor and consequently improves the alkaline peroxide treatment (9).

Fig.9 shows that with increasing DTPA percentage in cooking liquor, the tear factor and breaking length increase until 0.3% addition. Further increase in DTPA percentage decreases the tear factor and breaking length. The W.R.V. decreases and the degree of polymerization (D.P.) increases by increasing DTPA percentage in cooking liquor. From these results, it can be concluded that addition of 0.3% DTPA as chelating agent during the alkaline peroxide pulping of bagasse enhances the efficiency of the cooking liquor towards delignification process and carbohydrate protection.

Comparison of optical properties of pulps

The brightness of the bagasse pulps obained by different treatments was compared in addition to other chemical, physical and strength properties. The brightness of the bagasse pulps produced with sodium

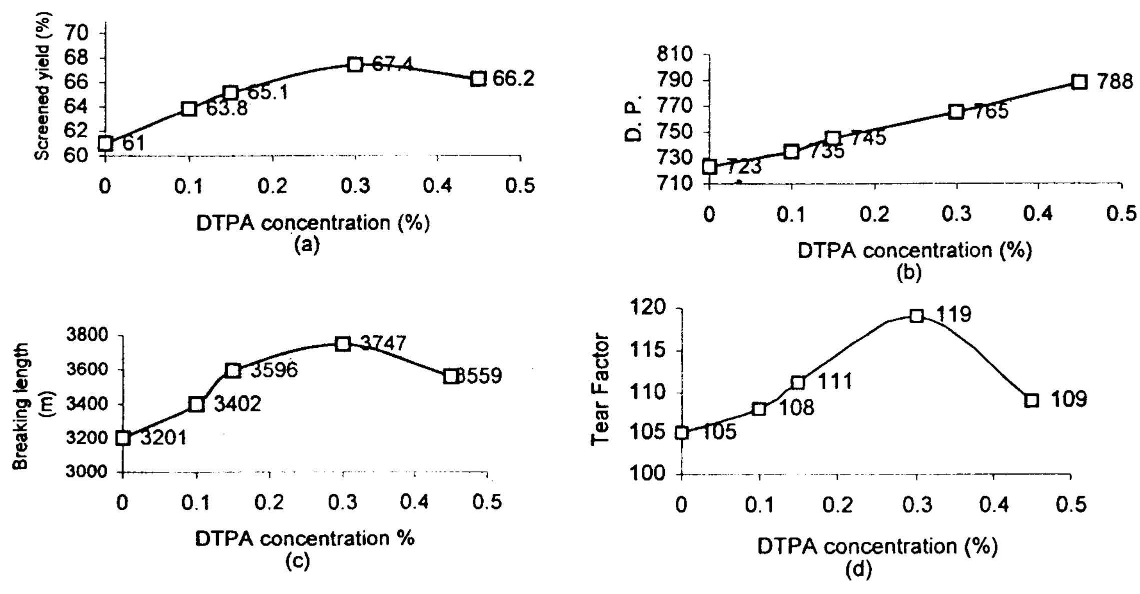

Fig.9: Effect of EDTA addition on pulp and paper properties.

hydroxide treatments decrease with increased sodium hydroxide concentration. It has brightness value of 36 and 32% ISO by using 8 and 10% sodium hydroxide respectively. Addition of 4% hydrogen peroxide during alkali treatment (8%) improves the brightness to a value of 38% ISO and it was in agreement with earlier results in producing chemimechanical pulp (CMP) from bagasse (8). In a preliminary trial to improve the effect of H_2O_2 in alkali treatment of bagasse, some additives were used such as chelating compound e.g. EDTA (0.3%) and DTPA (0.3%) or oxidizing catalyst as 1,10-phenanthroline. Table 10 shows that using of chelating compounds enhances the effect of H_2O_2 on the brightness property during alkaline treatment. It attains a value of 38% ISO by using $NaOH/H_2O_2$ treatment giving brightness values of 43 and 45% ISO on addition of EDTA and DTPA respectively. This is because of enhancement in the positive effect of these chelating compounds on decreasing destructive effect of transition element on H_2O_2. Also using of 1,10 phenanthroline has satisfactory effect on brightness where it attains 42% ISO in comparison with 38% ISO without using the catalyst.

Effect of beating method on paper properties, at different pulping time during $NaOH/H_2O_2$ pulping of bagasse

In order to evaluate the effect of beating method on paper properties at different pulping time and temperature during $NaOH/H_2O_2$ semichemical pulping of bagasse, the pulping conditions like alkali charge, peroxide concentration, liquor ratio and fibrillation time were held constant as 8%, 4%, 6:1 and 5 min respectively. After cooking, all samples were divided into portions, one of them was beaten in Jokro-Mill (method A) and the other was beaten in electrical blender (method B). Table 11 shows that in case of beating in Jokro-Mill (method A), the tear factor increases from 86.5 to 117 by increasing pulping time from 60 to 240 min. On the other hand, in case of beating in electrical blender (method B), it increases from 95.6 to 122 by increasing pulping time from 60 to 240 min. Breaking length in case of method A, increases from 2309 m at 60 min. to 2625 m at 240 min. Also in case of method B, it increases from 2386 m at 60 min. to 2798 m at 240 min, i.e., by increasing pulping time and using beating method B, some improvements in pulp properties were noticed.

The density of paper increases by increasing pulping time, it reaches to 0.357 and 0.333 g/cm³ at 240 minutes by using beating method A and B, respectively, i.e., by increasing pulping time and by beating in Jokro-Mill.

Table 11 shows also that the tear factor increases by increasing cooking temperature, it varied from 83.4 to 129 and from 110 to 132 when the temperature increased from 30 to 80°C, and using the beating methods, A and B, respectively. Breaking length increases by increasing temperature from 2395 and 1998 m at 30°C to3831 and 3892 m at 80°C by using method A and B, respectively. There is some improvement in the density of paper sheet by beating in Jokro-Mill. It could be concluded that both methods could be used for beating. Method B gave higher tear factor, while method A gave higher density but both

Table 10. Effect of some additives during $NaOH / H_2O_2$ treatment on optical properties.

	Pulping condition					
NaOH (%)	H_2O_2 (%)	Time (min)	Temperature (°C)	Additives (%)	ISO Brightness (%)	
9	8	-	60	90	-	36
6	10	-	60	90	-	32
11	10	-	120	60	-	27
44	8	4	120	60	-	38
21	8	4	120	60	0.3% EDTA	43
17	8	4	120	60	0.3% DTPA	45
58	8	4	120	60	1mmol 1,10-phenanthroline	42

Table 11. Effect of beating method on pulp properties during NaOH / H_2O_2 pulping of bagasse.

Time min	Temp °C	Beating method	Tear factor	Breaking length (m)	Density (gm/cm³)
180	30	A	83.4	2395	0.324
		B	110	1998	0.277
180	40	A	107	2558	0.333
		B	114	2609	0.310
180	50	A	109	2883	0.374
		B	119	2827	0.329
180	60	A	117	3472	0.381
		B	124	3370	0.341
180	70	A	126	3731	0.390
		B	130	3687	0.354
180	80	A	129	3831	0.398
		B	132	3892	0.366
60	40	A	86.5	2309	0.308
		B	95.6	2386	0.284
120	40	A	100	2442	0.319
		B	109	2414	0.306
150	40	A	105	2503	0.324
		B	111	2503	0.295
180	40	A	106	2558	0.333
		B	114	2609	0.310
240	4	A	117	2685	0.357
		B	122	2798	0.333

8% NaOH, 4% H_2O_2 LR 6:1 fibrillation time 5 min, A: Beaten in Jokro- Mill, B: Beaten in electrical blenders

have comparable breaking length.

CONCLUSIONS

Alkaline hydrogen peroxide semichemical pulping was carried out using 4-8% NaOH and 2-4% H_2O_2, NaOH/ H_2O_2 ratio varied from 4:1 to 1:1, for 1-4 h at 30-80°C, liquor ratio being 4:1-8:1 and fibrillation time 3-12 min. It was found that the alkaline peroxide semichemical pulping is superior in the total yield (about 95%) and screened yield (about 65%), it gave lower permanganate number and lower pentosan content. Also alkaline H_2O_2 pulp is superior in DP, tear and optical properties but inferior in breaking length compared with alkali pulping. The following optimum conditions are recommended: NaOH 8%, H_2O_2 4% (based on o.d. bagasse), temperature 80°C, treatment time 3h, liquor ratio 6:1 and fibrillation time 12 min.

EDTA (0.1-0.45%), DTPA (0.1-0.45%) and 1,10-phenanthroline (0.2-2 mmol) in pulping liquor (0.024-0.24% based on o.d. bagasse) were added during alkaline peroxide treatment under the conditions of 8% NaOH, 4% H_2O_2, LR 6:1 for 120 min., at 60°C and fibrillation time 5 min. It was found that, under these conditions, these additives have a positive effect on the pulping process. The optimum additions of EDTA, DTPA and 1,10-phenanthroline observed are at 0.3%,0.3% and 1mmol respectively. At these percentages, the screened yield increases by 14.6, 10.5 and 3% while permanganate no decreases by 21.5, 7.3 and 3%. The D.P. increases by 9, 5.8 and 0.6%, tear factor increases by 10.5, 13.3 and 9.5% and breaking length increases by 14.5, 17.1 and 14% respectively. In addition, the brightness of their pulps were improved. The brightness gains are about 18, 13% and 11% ISO on using DTPA, EDTA and 1,10 phenanthroline, respectively.

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