Delignification of Bagasse by using separate Alkali and Caro's Acid Treatments

Hussein Abou-Yousef, Mohamed El-Sakhawy, El-barbary M. Hassan and Samir Kamel
National Research Centre, Cellulose and Paper Department, Tahrir St., Dokki, Cairo, P.O.-12622, Egypt

ABSTRACT

Bagasse delignification by using separate alkali and Caro's acid treatments is considered as a promising process to prepare high yield bagasse pulp. This could be achieved via-two-stage technique (NaOH/Caro's acid) and three-stage technique (NaOH/Caro's acid/NaOH) The two techniques were practiced at low temperatures and atmospheric pressure. Three-stage techniques provide a possibility to produce chemical pulps, which have the advantages of both mechanical pulp (high yield pulp), and chemical pulp (good strength properties). At moderate concentration of Caro's acid used (3.0, 4.5% based on raw materials), three-stage technique has higher delignification selectivity than that of two-stage technique. Three-stage techniques produced pulps of higher breaking length and burst factor than that produced by two-stage techniqes. Tear factor of pulps produced by two-stage techniques has the superiority.

INTRODUCTION

Although experience of producing bagasse pulp dates back more than hundred years (1), high-yield pulping of bagasse was not feasible until disc refiners were introduced. A great deals of work has been done to produce bagasse high-yield pulp, primarily for production of newsprint, but also for other grades of paper (2-4). It has been proven that bagasse mechanical pulp, without chemical pretreatment, cannot replace wood mechanical pulp mainly because of its poor strength properties (5-6). However, bagasse chemimechanical pulping processes have gained increasing attention in recent years owing to its improved strength properties with high pulp yield in the range of 80-90% (7-8).

There have been many reasons for the slow development of bagasse high-yield pulp production, and one of the important reasons has been the difficulty in finding a process which is both reliable in technique and simple to carry out. Also, knowledge both of bagasse as paper-making material and of bagasse pulping processes have not always been satisfactory, especially in comparison with what has been achieved in terms of wood high-yield pulping. It was found that Caro's acid could be very effective in delignification of bagasse at low temperature and atmospheric pressure (9).

The objective of this study was to investigate the production of bagasse high-yield pulp based on separate alkali and Caro's acid treatment without disc refiner stage. The treatments can be practiced at low temperatures, at atmospheric pressure and low concentrations of chemical used (NaOH, H_2SO_5), and consequently it is expected that this study may lead to prepare chemical bagasse pulp which has the advantages of both mechanical pulp (high yield) and chemical pulp (good strength properties).

EXPERIMENTAL

Material

Depithed bagasse-delivered from Edfo mill in Aswan, Egypt-was used in this study. The chemical constituent of depithed bagasse was estimated as follows: lignin 20%, α-cellulose 42.3%, pentsan content 21.9% and ash content 1.98%.

Methods

Preparation of Caro's acid (presulphuric acid)

Adding concentrated sulphuric acid (95%) to a solution of hydrogen peroxide (32%), in flask kept in an ice bath, resulted in formation of presulphuric acid (Caro's acid). The Caro's acid concentration was determined by the method proposed by Greenspan and Mackeller (10).

Pulping : Bagasse pulping was carried out via two techniques

(a) Two-stage pulping (NaOH/caro's acid) in which bagasse was firstly treated with 3% NaOH (based on raw material) at 50°C for one hour at 10:1 liquor ratio, then followed by an oxidative delignification stage using Caro's acid concentrations 1.5, 3.0, 4.5 and 6.0% (based on raw material) at different pulping temperatures of 30°C and 40°C for 180

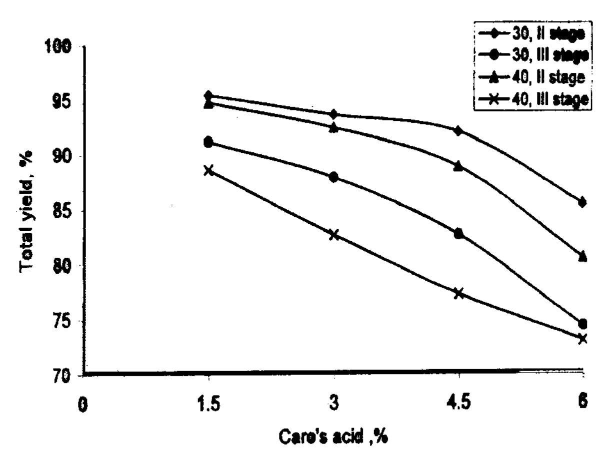

Fig. 1 Effect of Caro's acid concentration on the total yield

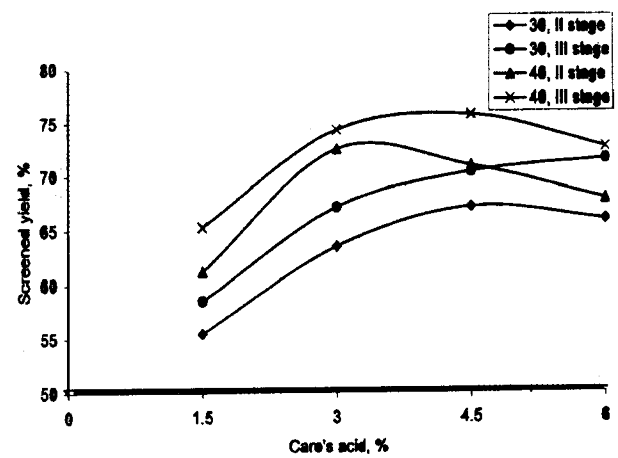

Fig. 2 Effect of concentration on the screened yield.

min at 10:1 liquor ratio.

b) Three-stage pulping (NaOH/ Caro's acid/ NaOH) in which bagasse was subjected to NaOH treatment before and after Caro's acid delignification. The treatment conditions of the first two stages are the same as that of two-stage pulping. The third stage was carried out by using 3% NaOH (based on pulp) at 70°C for 60 min at 10:1 liquor ratio.

The pulps produced in both techniques were disintegrated mechanically.

- Pulp test: Kappa number by SCAN-C 1:77 standard method.
- Paper sheet formation: Pulps were beaten to 40°SR in a Jokro Mill beater. Paper sheets of basis weight 68/gm² were formed. The strength properties of paper sheets were carried out according to Tappi standard.

RESULTS AND DISCUSSION

Yield and kappa number

In both techniques (two and three-stage), the bulk delignification phase occurred through Caro's acid stage (9). The study was focused on the variation of the most important pulping factors, Caro's acid concentration and the pulping temperature applied during this stage, and illustrating their effects on the final properties of the pulps produced by both techniques. Fig. 1 shows the effect of Caro's acid concentration in range from 1.5 to 6% based on raw material at temperatures of 30 and 40°C, on the total yield of the pulps produced by the two and three-stage techniques. It is clear that increasing Caro's acid dose and/or temperature in the oxidative delignifying stage led to decrease in the total yield. Also, the two-stage techniques have higher yield than that produced in case of three-stage technique. This may be attributed to the effect of sodium hydroxide in the third stage where more carbohydrate dissolution takes place in addition to lignin removal. The screened yield of pulps is considered important property that reflects the efficiency of the pulping process.

Fig 2 shows the effect of Caro's acid concentration at 30 and 40°C, on the screened yield of the two and three-stage techniques. As shown in Fig. 2, increasing the applied temperature in Caro's acid stage improves the screened yield of pulp from the two techniques. Also, at certain temperature (30 and 40°C), the screened yields, pass through maximum with increasing of Caro's acid dose (3-4.5%). The three-stage techniques produced pulps of higher screened yield than that produced from two-stage technique in the whole range of Caro's acid concentrations. This was attributed to the lower amount of rejects in pulp produced by three-stage than that in two-stage. This reflects the highest delignification efficiency of the three-stage with respect to two-stage technique.

Fig 3 shows the effect of Caro's acid concentration on kappa number of pulps produced by two and three-stage technique. In both techniques kappa number decreases with increase of temperature and/or Caro's acid dose. Also, moderate Caro's acid concentrations (3,4.5% based on raw material) are sufficient to achieve the bulk delignification of bagasse. After these concentrations, slight decrease in kappa number was obtained. Fig. 3 shows the effect of the third stage (sodium hydroxide treatment) in enhancing the delignification process where, at constant temperature and/or Caro's acid dose. Also, moderate Caro's acid concentrations (3, 4.5% based on raw material) are sufficient to achieve the bulk delignification of bagasse. After these concentrations slight decrease in kappa number was obtained. Fig. 3

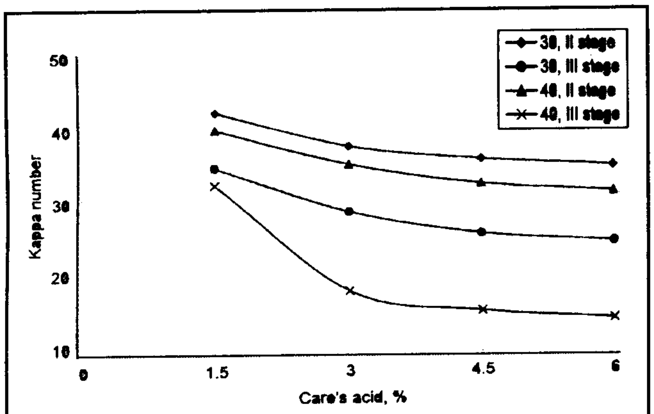

Fig. 3 Effect of Caro's acid concentration on the kappa number.

shows the effect of the third stage (sodium hydroxide treatment) in enhancing the delignification process where, at constant temperature and Caro's acid dose, pulps produced by three-stage technique has lower kappa number than that of two-stage. This demonstrates that the third sodium hydroxide stage has double effect since it extracts the lignin fragments produced in the second stage and also, delignifies a portion of uncooked rejects in the same stage.

Selectivity

When different pulp processes have been designed to produce the same yield, the process that produces high-screened yield with the lower kappa number of pulp has the highest selectivity. The pulping selectivity as expressed by the ratio between screened yield and kappa number was used for evaluation of pulping parameters. As proper selectivity implies high yield and low pulp lignin content for easy bleaching, high selectivity ratio are expected (11). Fig 4 shows the selectivity as a ratio between the screened yield and kappa number at different pulping conditions for both two and three-stage techniques. It is clear that the pulp produced by three-stage process has always the higher selectivity over all the studied range of Caro's acid dose and pulping temperatures. Also, higher temperature provides higher selectivity. The three stage pulping technique at 40°C provides much higher selective delignification.

The strength properties

Table 1 shows the strength properties of pulp produced by both two and three-stage techniques at different pulping conditions. The pulp produced by the two and three-stage techniques are characterised by the high of lignin content because the effect of the oxidative delignification stage (Caro's acid stage) in which the delignification process depends on the change of lignin chromophors. Lignin can have an important effect on the strength properties of pulp (12). It may affect the surface properties and cause the fibres to be stiffer and less conformable. This can be correlated to the increase in breaking length, in case of two-stage process, with increase of degree of delignification (lowering of kappa number).

In case of three-stage process the increase of Caros' acid dose, which led to decrease in kappa number, resulted in increasing of breaking length till moderate dose of Caro's acid (3-4.5%), after which breaking length decreased (Table 1). It is likely that the high dose of Caro's acid followed by sodium hydorxide treatment in third stage may attack on the amorphous part of which and damage dislocations of the cellulose microfibrils as a result the fibre strength decreases (13). It can be seen from the results in Table 1 that the three-stage process led to pulps of higher breaking length than the pulps

Table 1 The strength properties of pulp produced by two and three-stage techniques at different pulping conditions.

Temp., °C	Caro's Acid, %	Two-stage process			Three-stage process		
		Breaking length, m	Burst factor	Tear factor	Breaking length, m	Burst factor	Tear factor
	1.5	2630	24.34	63.55	3355	25.73	57.24
	3.0	2875	24.57	63.34	3417	25.77	56.88
30							
	4.5	3357	24.25	62.80	3485	25.79	56.70
	6.0	3465	24.11	60.85	3455	25.70	54.31
	1.5	3260	23.72	62.35	3390	26.25	56.34
	3.0	3395	23.56	62.21	3440	26.56	55.11
40							
	4.5	3450	22.23	60.23	3470	24.33	53.21
	6.0	3478	22.22	58.67	3355	24.11	51.76

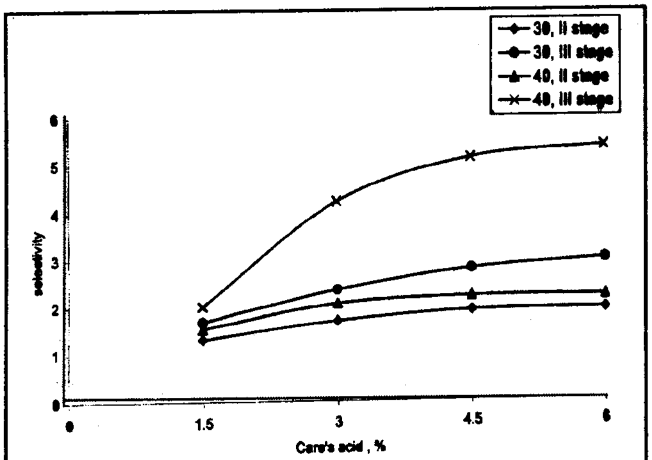

Fig. 4 Effect of Caro's acid concentration on the selectivity.

produced by two-stage process in case of moderate Caro's acid dose applied. This may be attributed to the fact that the alkali, in third stage, causes increase in acidic group through alkali hydolysis of preexisting esters in the hemicellulose fraction of the pulp and consequently the third alkali treatment led to strengthening of the pulp (14). According to the results shown in Table 1, pulps produced from three-stage technique have less tear factor than that produced from two-stage technique. This may be attributed to the association of tear strength with the extent of amorphous regions, which may be damaged in pulps produced from the three-stage process (15).

As shown in Table 1, burst factor of pulps produced from three-stage technique is slightly higher than that of pulps produced from two-stage technique. This may be attributed to the flexibility of pulp fibres produced from three-stage process due to the third-stage alkali treatment which extract considerable amount of lignin fragment and hence, the fibre stiffness caused by the presence of lignin could be reduced (12), and as result of that the interfibre bonding could be enhanced.

CONCLUSION

Bagasse high yield pulp has been prepared by using separate alkali and Caro's acid treatments dependent on two-stage (NaOH/Caro's acid) and three-stage (NaOH/ Caro's Acid/NaOH) techniques. The bulk of delignification, Caro's acid stage, has been carried out at low temperatures (30, 40°C) and at Caro's acid concentrations of 1.5 to 6.0% based on raw material. High degree of delignification and good strength properties can be achieved at moderate concentration of Caro's acid (3.0 4.5% based on raw material). Three-stage technique produces pulps possessing higher delignification selectivity than that by two-stage technique.

REFERENCES

1. Atchison J.E.: Pulp and Paper, 69 (7), 125-131 (1995).
2. Jolley P.R. and Cusi D.S.: "Bagasse Newsprint", UNIDO Expert Group Meeting on Pulp and Paper, Vienna, Austria, 68, (1971).
3. Lopez P. and Carica O.L. : Tappi Pulping Conf. 31, (1984).
4. El-saied H., El-Sakhawy M. and El- Shawadefy I.M. : IPPTA J., 14 (1), 1-14, (2002).
5. Zanuttini M. : Appita, 44 (4), 257 (1991).
6. Moldenius S. : J. Pulp Pap. Sci., 10 (6), J. 172, (1984).
7. Zanuttini M., Citroni M. and Marzocchi V. : Holzforschung, 52 (4) 405-411, (1998).
8. Jones T.G. and Richardson J.D.,: Appita J., 54 (3), 265 (2001).
9. Hussein Abou-Yousef: J. Korea Tappi, 33, 5, (2001).
10. Greenspan F. and Mackeller G. : Anal. Chem., 20 (11), 1061 (1948).
11. Lonnberg K.B.: AIChE, Products Symposium Proceedings, 17-22, (1991), Los Angles, Tappi Press, 45, (1992)
12. Raymond A.Y.,: Cellulose, 1, 107 (1994).
13. Raymond A.Y. and Eric O.F.: Cellulose, 3, 21, (1996).
14. Akira I.: Cellulose, 4, 99 (1997).
15. Akira I. and Atalla R.H.: Cellulose, 5, 309 (1998).