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SODA PULPING OF SAPWOOD

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JAHAN, M. S., RAHMAN, S. M., RASHID, M. H. O. & MAHBUBAR RAHMAN, A. H. M. 2004. Soda pulping of sapwood. Pulping of sapwood by soda and soda-anthraquinone (AQ) processes was done with varying cooking variables, namely cooking time, temperature, alkali concentration and liquor ratio. At 20% alkali concentration in 2 hours of cooking at 170 °C, sapwood produced pulp of about 42% yield with kappa number of about 25. The pulp yield was increased by 2–3% on oven-dried (o.d.) wood with an addition of 0.1% AQ in soda liquor at the targeted kappa number of 25. The addition of AQ in soda liquor saved cooking time by 1 hour or alkali concentration by 2% on o.d. wood. The physical properties of sapwood pulp from soda-AQ process were greater than those of pulp from soda process.

Key words: Soda-anthraquinone process – pulp yield – kappa number – strength properties

JAHAN, M. S., RAHMAN, S. M., RASHID, M. H. O. & MAHBUBAR RAHMAN, A. H. M. 2004. Pempulpaan kayu gubal melalui proses soda. Pempulpaan kayu gubal melalui proses soda dan proses soda-antrakuinon (AQ) dijalankan menggunakan masa masakan, suhu, kepekatan alkali dan nisbah air rebusan yang berlainan. Pada 20% kepekatan alkali dan masa masakan selama 2 jam serta pada suhu 170 °C, kayu gubal menghasilkan pulpa sebanyak 42% dengan nombor kappa 25. Hasil pulpa bertambah 2–3 % berdasarkan berat kering ketuhar kayu dengan pertambahan 0.1% AQ ke dalam air rebusan pada nombor kappa sasaran 25. Penambahan AQ ke dalam air rebusan menjimatkan masa masakan selama 1 jam atau kepekatan alkali sebanyak 2% berdasarkan berat kering ketuhar kayu. Ciri-ciri fizikal pulpa kayu gubal daripada proses soda-AQ lebih baik daripada pulpa daripada proses soda.

Introduction

The demand for pulp and paper in Bangladesh is about 0.4 million tons year^{-1} but Bangladesh produces about 0.2 million tons year^{-1}. Therefore, more pulp mills are needed in Bangladesh. Presently, pulp mills in Bangladesh use bamboo, bagasse and mixed hardwood. Unfortunately, these existing conventional raw materials do not permit more pulp mills in Bangladesh. Therefore alternative raw materials have to be sought.

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Sawmills in Bangladesh use heartwood and reject sapwood. The sapwood is being used as domestic fuel. Alternative uses of sapwood such as pulping raw material will provide an extra income to sawmill and also increase the supply of fibrous raw material in pulp mills.

The wood in young trees and the outer wood of older trees, capable of conducting sap and contains living parenchyma which stores carbohydrates, fats and other foods is referred to as sapwood and is light in colour (Kocurek & Stevens 1997). Sapwood is located between the cambium and heartwood. The transition from sapwood to heartwood is accompanied by an increase in extractive content (Miller 1999).

Many studies have been done on the difference between sapwood and heartwood pulping. Neutral sulphite semi-chemical (NSSC) and sulphate pulping studies on *Populus* showed that the heartwood and sapwood differed considerably in fibre length and chemical properties (Dix & Roffael 1992). NSSC pulps from sapwood has higher degree of whiteness, greater tear strength and slightly lower yields compared with those from heartwood. However, there are no significant differences between heartwood and sapwood pulps with regard to tear length, burst strength and residual lignin content. With sulphate pulps, the pulping condition significantly affects the quality of pulp made from sapwood and heartwood. Sulphate pulp from heartwood has slightly higher yield and higher ash content than that of sapwood. However, there is no significant difference with regard to whiteness or lignin content. Clone-dependent differences are found in the strength properties of sulphate pulps from sapwood and heartwood (Dix & Roffael 1992).

The present investigation studied the pulping of sapwood by soda and soda-anthraquinone (AQ) processes with different cooking conditions.

Materials and methods

Material

Sapwood was collected from a sawmill in Dhaka. It was cut to about 2 × 1 × 1 cm in size.

Pulping

Pulping was carried out in a batch cylindrical reactor (20 l) heated by means of electrical resistance and was rotated by a motor. The normal charge was 1 kg of moisture free sapwood. The following parameters were maintained:

- Alkali concentration was varied from 18–24% as NaOH on oven-dried (o.d.) sapwood for soda process and 16–22% for soda-AQ process.
- Cooking temperature was varied from 160 to 180 °C.
- Cooking time was varied from 1 to 4 hours at the maximum temperature.
- Liquor to material ratios were 4, 5 and 6.
- 0.1% AQ (on o.d. sapwood) was used in soda-AQ process.

After digestion, the pulp was washed until free from residual chemicals. The pulp yield was determined as percentage of o.d. raw materials. The kappa number of the pulps was determined according to T 236 Tappi Test Methods (2000–2001).

Evaluation of pulps

Sapwood pulp was beaten in a Valley beater to 40 °SR and hand sheets of about 60 g m^{-2} were made in a Rapid Kothen Sheet Making Machine according to German Standard Methods number 106 (Anonymous 1958). The sheets were tested for tensile (T 404os 61), burst (T 403m 53) and tear strength (T 414m-49), double fold (T 423m-50) according to Tappi Test Methods (2000–2001).

Results and discussion

Table 1 shows the effect of alkali concentration on pulping of sapwood. The other variables, namely cooking temperature, time and material ratio, were held constant at 170 °C, 2 hours and 1:5 respectively. Fully chemically defiberised pulps were obtained even with alkali concentration of 18% but the kappa number was significantly higher (Table 1). An increase of 2% alkali concentration decreased the kappa number by 14.4 points. The kappa number reduction was small with further increase of alkali. The pulp yield decreased by 0.4% with increasing alkali concentration, from 18 to 20%; again increase of alkali concentration to 22% the decrease in pulp yield was 1.1%.

The tear index of sapwood pulp decreased with increasing alkali concentration (Table 1). The burst index and breaking length increased with increase in alkali concentration from 18 to 20%. However, these properties decreased with further increase in alkali concentration. Good physical properties and good yield-kappa relationship were obtained at 20% alkali concentration.

The pulp yield and kappa number decreased with cooking time (Table 2). The kappa number was lowered after 2 hours of cooking. The tear index also decreased with cooking time. The burst index and breaking length decreased after 2 hours of cooking. Therefore, 2 hours' cooking with 20% alkali were considered optimum.

Temperature had no major effect other than on the rate of pulping as shown in Table 3. However, at higher temperature, the process becomes less selective for lignin. The kappa number was higher at 160 °C. The kappa number and pulp yield decreased with increase in temperature from 160 to 170 °C. Further increase in temperature reduced the kappa number further. Better physical properties were obtained at 170 °C.

Table 1 Effect of alkali concentration on pulp yield and pulp properties in soda pulping of sapwood

Alkali concentration (% on o.d. sapwood)	Pulp yield (%)	Kappa number	Tear index (mN m^2g^{-1})	Burst index (kPa m^2g^{-1})	Breaking length (km)	Double fold number
18	42.1	39.1	7.2	3.9	5.4	291
20	41.7	24.7	7.2	4.0	5.6	322
22	40.6	22.9	7.0	3.8	5.5	332
24	39.3	22.1	6.7	3.5	5.3	311

Cooking time 2 hours; temperature 170 °C; material to liquor ratio 1:5

To ensure bulk penetration of all chips, it is important that sufficient liquor be charged to the digester to completely immerse the chips. Table 4 shows that at 1:4 material to liquor ratio, the kappa number was higher possibly due to improper penetration of chemical in the sapwood chips. There was no significant difference in pulp yield and kappa number in the 1:5 and 1:6 liquor ratios. The physical properties of pulp at all ratios remained almost similar except for breaking length at 1:4 ratio. Liquor ratio of 1:5 was most suitable for sapwood pulping.

AQ charge was constant at 0.1% on o.d. sapwood. Fully chemically defiberised pulp could be obtained at 16% alkali charge although kappa number was higher than the targeted kappa number of 25 (Table 5). Initially, kappa number reduction was very rapid with increasing alkali concentration but later on slowed down. Figure 1 shows the advantage of soda-AQ process over soda process. The higher rate of delignification in the presence of AQ is reflected in the production of soluble lignin with a higher phenoloic hydroxyl content (Evstigneyev *et al.* 1992), indicating more extensive cleavage of ether linkage. An amount of 0.1% AQ in soda liquor saved the alkali concentration by 2% on o.d. sapwood to reach the desired level of

Table 2 Effect of cooking time on pulp yield and pulp properties in soda pulping of sapwood

Cooking time (hours)	Pulp yield (%)	Kappa number	Tear index (mN m^2g^{-1})	Burst index (kPa m^2g^{-1})	Breaking length (km)	Double fold number
1	42.9	30.7	7.3	3.8	5.3	284
2	41.7	24.7	7.2	4.0	5.6	322
3	40.9	23.9	7.0	3.9	5.5	341
4	38.7	22.8	6.8	3.7	5.3	318

Alkali concentration 20%; temperature 170 °C; material to liquor ratio 1:5

Table 3 Effect of temperature on pulp yield and pulp properties in soda pulping of sapwood

Cooking temperature (°C)	Pulp yield (%)	Kappa number	Tear index (mN m^2g^{-1})	Burst index (kPa m^2g^{-1})	Breaking length (km)	Double fold number
160	43.0	29.8	7.3	3.7	5.2	246
170	41.7	24.7	7.2	4.0	5.6	322
180	40.1	23.6	6.9	3.8	5.4	199

Cooking time 2 hours; alkali concentration 20%; material to liquor ratio 1:5

Table 4 Effect of material to liquor ratio on pulp yield and pulp properties in soda pulping of sapwood

Liquor ratio	Pulp yield (%)	Kappa number	Tear index (mN m^2g^{-1})	Burst index (kPa m^2g^{-1})	Breaking length (km)	Double fold number
1:4	42.0	30.1	7.0	3.8	5.1	320
1:5	41.7	24.7	7.2	4.0	5.6	322
1:6	41.8	24.9	7.3	3.9	5.6	341

Cooking time 2 hours; temperature 170 °C; alkali concentration 20%

Table 5 Effect of alkali concentration on pulp yield and pulp properties in soda-AQ pulping of sapwood

Alkali concentration (% on o.d. sapwood)	Pulp yield (%)	Kappa number	Tear index (mN m^2g^{-1})	Burst index (kPa m^2g^{-1})	Breaking length (km)	Double fold number
16	45.4	30.4	8.0	3.8	5.5	324
18	45.0	25.5	8.6	4.8	6.1	350
20	44.4	24.2	8.6	4.6	6.0	354
22	43.9	23.2	8.5	4.4	5.9	331

Cooking time 2 hours; temperature 170 °C; material to liquor ratio 1:5

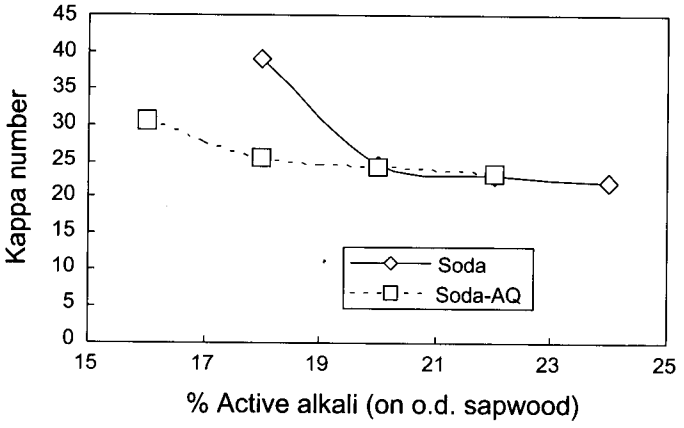

Figure 1 Effect of alkali concentration on delignification of sapwood in soda and soda-AQ pulping

delignification. This is in agreement with other studies on soda-AQ process of wood (Ghoosh *et al.* 1978, Eckert *et al.* 1984).

The pulp reached a desired kappa number of about 25 in 18% alkali in 2 hours of cooking (Table 6). In 1 hour of cooking kappa number was high. However, after 2 hours the kappa number did not reduce. Figure 2 shows that the soda and soda-AQ processes produced pulps of almost similar kappa number.

Depending on a mill's circumstances, the alkali charge may be kept constant and AQ be used to achieve a higher delignification rate by faster cooking time or keep the cooking time constant and reduce the alkali concentration by 2% on o.d. sapwood.

Table 6 Effect of cooking time on pulp yield and pulp properties in soda-AQ pulping of sapwood

Cooking time (hours)	Pulp yield (%)	Kappa number	Tear index (mN m^2g^{-1})	Burst index (kPa m^2g^{-1})	Breaking length (km)	Double fold number
1	48.3	31.1	8.8	4.4	5.8	316
2	44.4	24.2	8.6	4.6	6.0	354
3	43.1	24.1	8.5	4.6	6.1	356
4	43.0	24.0	8.3	4.4	5.9	328

Alkali concentration 20%; temperature 170 °C; material to liquor ratio 1:5

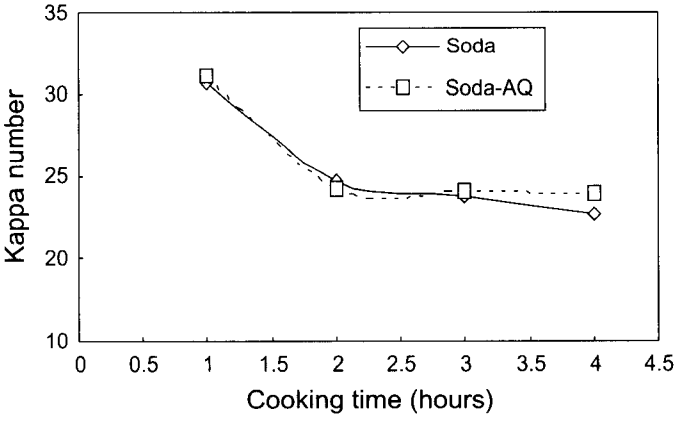

Figure 2 Effect of cooking time on delignification of sapwood in soda and soda-AQ pulping

Figure 3 shows the relationship between pulp yield and kappa number of soda and soda-AQ pulps with regard to varying cooking time. Pulp yield in soda-AQ process showed higher value than that of soda process at any kappa number. At kappa number 25, soda-AQ process produced 4% higher pulp yield than soda process. The increase in pulp yield in soda-AQ process is due to the stabilisation of reducing end group in polysaccharides (Fleming *et al.* 1978, Lowendahl & Samulson 1978).

Figures 4 to 7 show the physical properties of soda and soda-AQ pulps at different points of delignification at °SR 40. All properties increased with increasing delignification up to certain level, after which the properties deteriorated.

The highest breaking length value was obtained at kappa number about 24 in both soda and soda-AQ pulps (Figure 4). In our targeted kappa number about 24 soda-AQ pulp produced 10% higher breaking length value as compared with soda pulp.

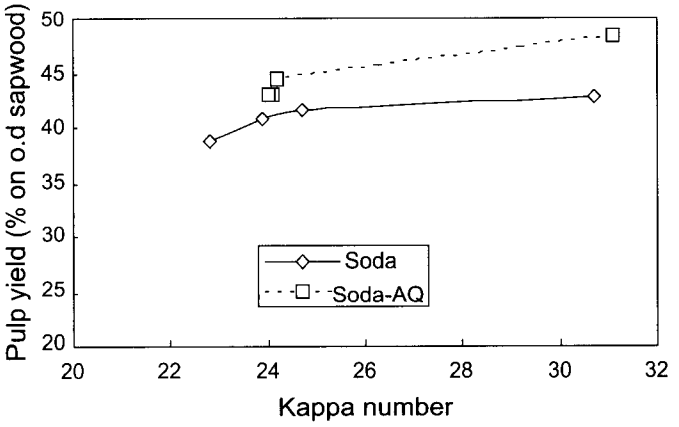

Figure 3 Relationship between kappa number and pulp yield of soda and soda-AQ pulps from sapwood

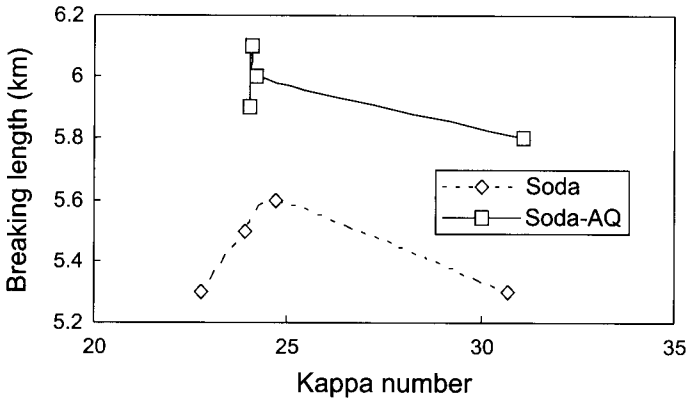

Figure 4 Relationship between kappa number and breaking length

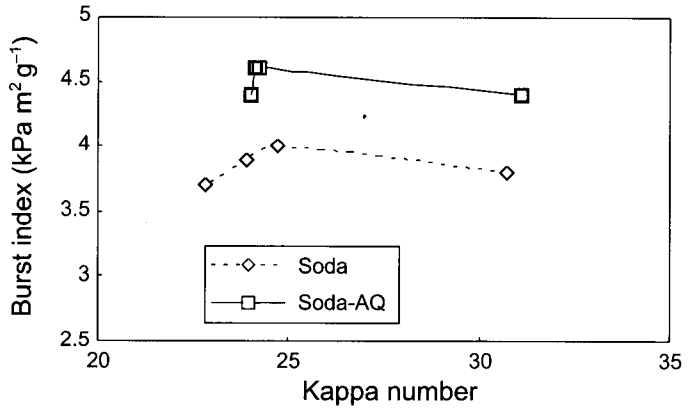

Figure 5 Relationship between kappa number and burst index

The burst index value of soda-AQ pulp was higher than that of soda pulp at any point of delignification. At kappa number about 24, it was about 4.6 in soda-AQ pulp and about 4 in soda pulp.

The tear index of soda and soda-AQ pulps with regard to kappa number at 40 °SR is shown in Figure 6. Soda-AQ pulp showed higher tear index at any kappa number than that of soda pulp. At kappa number 24, soda-AQ pulp showed about 21% higher value than soda pulp.

Double fold number-kappa number relationship of soda and soda-AQ pulps is shown in Figure 7. Soda-AQ pulp showed superiority in almost all points of delignification. After kappa number 24, it decreased abruptly. Maximum value was obtained at kappa number about 24 in both pulps.

The relationship between breaking length and tear index of soda and soda-AQ pulps of kappa number about 25 at different pulp freeness is shown in Figure 8. Soda-AQ pulp had higher breaking length than the soda pulp and its tear index was better. At any breaking length, soda-AQ pulp showed higher tear index. At breaking length 5 km, it had 30% higher tear index than soda pulp.

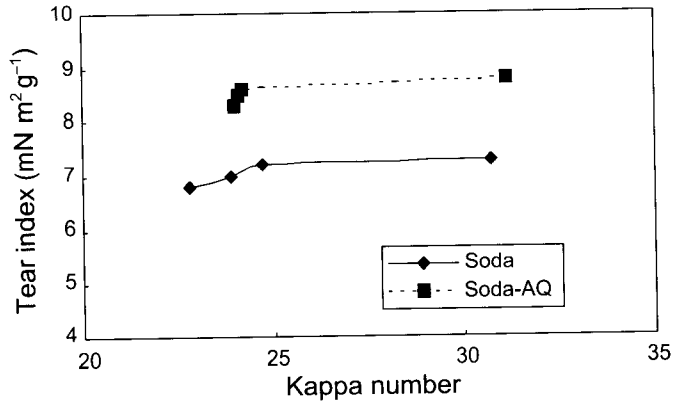

Figure 6 Relationship between kappa number and tear index

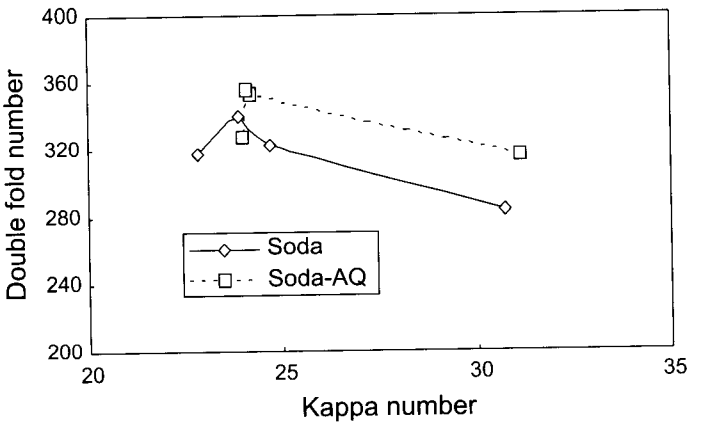

Figure 7 Relationship between kappa number and double fold number

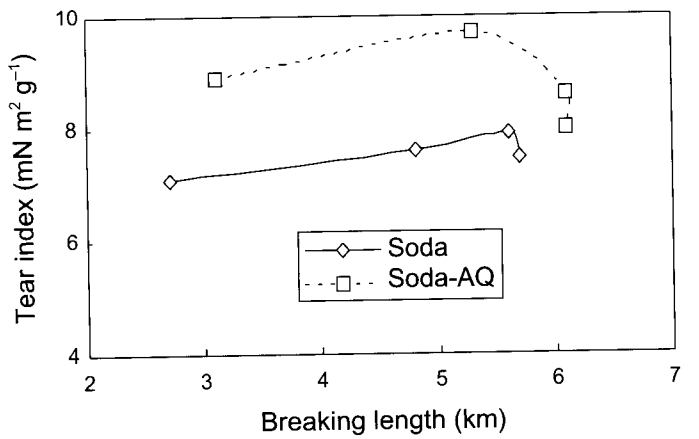

Figure 8 Relationship between breaking length and tear index of soda and soda-AQ pulps at kappa number 25

Conclusions

Sapwood yielded pulp of about 42% with kappa number of about 25 at optimum conditions in the soda process. An addition of 0.1% anthraquinone to the soda liquor increased pulp yield as much as 2% on oven-dried sapwood at the same kappa number. Pulp yield and kappa number decreased with increasing alkali concentration, cooking time and temperature. At the same time, anthraquinone saved 2% alkali to reach the desired level of delignification. In the optimum condition, sapwood produced pulp of 5.6 km breaking length with tear index of 7.2 mN m^2g^{-1}. An addition of anthraquinone in the soda liquor produced pulp of better strength properties.

References

ANONYMOUS. 1958. *German Standard Methods No. 106. Handsheet Forming for Physical Tests of Pulp.* German Chemist's and Engineer's Publication, Dramstadt.

DIX, B. & ROFFAEL, E. 1992. Behavior of poplar sapwood and heartwood during pulping. *Holz-als-Rohund Werkstoff* 50: 1, 5–10, 38.

ECKERT, R. C., PFEIFFER, G. O., GUPTA, M. K. & LOWER, C. R. 1984. Soda-AQ pulping of Douglas fir. *Tappi Journal* 67(11): 104.

EVSTIGNEYEV, E., MAIYOROVA, H. & PLATONOV, A. 1992, Lignin functionalization and the alkaline delignification rate. *Tappi Journal* 75(5): 177–182.

FLEMING, B. I., KUBES, G. J., MACLEOD, J. M. & BOLKER, H. I. 1978. Soda pulping with anthraquinone. *Tappi Journal* 61(6): 43–46.

GHOOSH, K. L., VENKATESH, V. & GRATZL, J. S. 1978. Soda-anthraquinone pulping of hardwoods—process models. *Tappi Journal* 61(8): 57–61.

KOCUREK, M. J. & STEVENS, C. F. B. 1997. *Pulp and Paper Manufacture. Volume 1: Properties of Fibrous Raw Materials and Their Preparation for Pulping.* Canadian Pulp and Paper Association, Montreal.

LOWENDAHL, L. & SAMULSON, O. 1978. Carbohydrate stabilization during soda pulping with addition of anthraquinone. *Tappi Journal* 61(2):19–21.

MILLER, B. R. 1999. *Wood Handbook—Wood as an Engineering Materials.* US Department of Agriculture, Madison.

TAPPI TEST METHODS. 2000–2001. CD version. Tappi Press, Atlanta.