Alkaline Pulp of Corn Stalks

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Abstract

Pulping of corn stalks was studied in soda, soda-anthraquinone (AQ), kraft and kraft-AQ processes. The time, temperature and alkali concentration were varied in soda process. In respect to kappa number and pulp yield, 1 hour cooking at 140^{0}C in 14% alkali were best conditions for corn stalks pulping. Pulp yield was increased by 5.5% and kappa number was reduced by 4.4 points with an addition of 0.05% AQ in the soda liquor. Breaking length was better in soda-AQ process than soda process but tear strength was inferior. In the kraft process, pulp yield was increased with increasing sulphidity and decreasing active alkali. The effectiveness of AQ in the low and high sulphidity kraft process was studied. Results showed that AQ was more effective in low sulphidity than high sulphidity. Strength properties in kraft processes were better than the soda and soda-AQ processes.

INTRODUCTION

Traditionally, forest based woody raw materials are the principal source of paper making fibres. The paper industry is considered to be the highest consumer of forest based cellulosic materials (1). World paper production has increased in the last few decades (2). This growth entails massive felling, which is gradually giving rise to deforestation and also its associated ecological problems.

In the last decade the global consumption of paper and board exceed from 231.6 million tonnes in 1989 (3) to 314.4 million tonnes in 1999 (4). This figure expected to increase further with increasing world population, and improved literacy and quality of life worldwide. This increasing trend of fibre demand creates an opportunity to non-woody materials as an alternative fibre sources. Nonwood or agro based fibres are derived from selected tissues of various mono or dicotyledonous plants and are categorized botanically as grass, bast, leaf or fruit fibre. Some nonwood fibres are classified with respect to production : fibre such as sugar cane bagasse, wheat straw, corn stalks are byproducts. Other nonwood fibres are grouped as "fibre plants" plants with high cellulose content that are cultivated primarily for the sake of their fibres such as jute, kenaf, flax, cotton etc.

In Bangladesh, pulp and paper mills use mixed hardwood, Gewa wood and bamboo. Unfortunately, pulp mills cannot run properly due to conventional fibre shortage. Therefore, we should find out alternative fibre resources like nonwood. The most widely used nonwood for paper making is straw, bamboo, bagasse, kenaf, jute, hemp etc. Nonwoods have lower lignin content than woods and generally easier to delignify as they have lower activation energy (5). It has been estimated that the total availability of nonwood fibres suitable for papermaking worldwide is approximately 2.5 billion tonnes per year (6) Like many other nonwoods, corn stalks have been considered as a possible source of raw material for manufacturing low grades of paper. In 1929, Webber described corn stalks pulping (7) but unfortunately results were not encouraging. Recently, Bangladesh has paid attention on maize cultivation. After harvesting of maize, stalks are left in the filed. Therefore, transportation of stalks from the field increases production cost. Hence stalks are being burnt in the field that is environmentally polluting. Considering these facts, an initiative has been taken to use wastes as high value added product.

In this investigation, an optimization of corn stalks pulping has been performed in soda process with varying cooking time, temperature and alkali concentration. The effect of anthraquinone (AQ) in soda pulping has also been done. Another set of experiment has been done in kraft and kraft-AQ processes with varying sulphidity and alkali concentration.

EXPERIMENTAL

Raw materials

Corn stalks were collected from the Savar region of Dhaka. It was sun dried and roots, leaves dart etc were removed. Then it was cut to 2-3 cm in length and pit was removed by hand. The moisture content of cornstalks was determined according to TAPPI standard Methods (T 18m-53). After determination of the moisture content of air dried corn stalks equivalent to 250 gm oven dried (o.d.) was weighed separately in a polyethylene bag for subsequent cooking experiments.

Cooking

All pulping experiments were performed in an autoclave of 5 liters capacity, made of stainless steel, rotating at 1 rpm, fitted with thermostat. The following parameters were maintained in soda process :

- Total alkali charge as sodium hydroxide; 10, 12, 14, 16% on o.d. raw materials.
- Liquor to fibre ratio, 6:1
- Temperature : 110, 130, 140, 150, 160 and 170°C.
- Cooking time at maximum temperature : 0, 30, 60 and 90 min.

In soda-AQ and kraft-AQ processes, 0.05% AQ on o.d. raw materials was used. In the kraft process, 11, 18 and 29% sulphidity was used and active alkali was varied to 12, 14 and 16% as Na_2O in each sulphidity.

Evaluation of pulps

Corn stalk pulps from soda, soda-AQ, kraft and kraft-AQ processes were beaten in a Valley beater. The samples were collected at different freeness and hand sheets of about 60g/m^2 were made in a Rapid Kothen Sheet Making Machine according to German Standard Methods DIN 106. 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 Standard Methods.

RESULTS AND DISCUSSION

Soda and Soda-AQ process

Pulp yield and kappa number

Table 1 shows the effect of operating variables on the pulp yield and kappa number of corn stalks. It is clearly seen from Table 1 that 60min cooking time at the maximum temperature even at 110°C is enough to achieve fibre liberation. However, sufficient delignification was not observed at 110°C. If alkali concentration is increased from 12 to 14% at this temperature (110°C), kappa number get reduced to 31.5 only from 33.2 kappa number was reduced to 23.4 from 33.2 with an increase of temperature from 110 to 140°C. Again an increase of tempertaure to 170°C, kappa number decreased to 15.6 and at the same time pulp yield was reduced drastically to 41.6%. Therefore, at higher temperature corn stalks pulp was degraded. Corn stalks may contain more p-hydroxy phenyl unit like straw. Therefore, corn stalks to not require high temperature like wood or other nonwood during alkaline pulping. Considering pulp yield and kappa number, 140°C produced the best results. At 140°C, pulp yield and kappa number were decreased to 48.9 and 20.5 from 51.2 and 27.4, respectively with an increase of alkali concentration to 16% from 10. Similarly, keeping an alkali concentration and temperature constant at 14% and 140°C, respectively, cooking time was varied from 0 to 90 min, result showed that pulp yield decreased from 52.3 to 49.2% with kappa number from 25.6. to 20.2.

Fig. 1 shows the effect of AQ in soda pulping of corn stalks. AQ has a beneficial effect on both pulp yield and kappa number. It is clearly seen that at the same condition an addition of 0.05% AQ increased the pulp yield by about 5% on o.d. corn stalks. The kappa number was lowered by 4.4 points. These results are in well accordance with the previous investigation (8). The increase in yield is due to the stabilization of carbohydrates against degradation, such as a peeling reaction (9). If alkali charge was reduced by 2% on o.d. corn stalks then

Table 1. Effects of operational variable on pulp yield and kappa number in corn stalks pulping

Alkali Concentration	Time at Temp. min	Temperature °C	Pulp yield, % on o.d. corn stalks	Kappa Number
12	60	110	54.1	33.2
14	60	110	53.6	31.5
12	60	130	52.4	29.7
14	60	130	51.3	28.8
10	60	140	51.2	27.4
12	60	140	50.9	26.1
14	60	140	50.5	23.4
16	60	140	48.9	20.5
12	60	150	46.7	19.6
14	60	150	46.3	19.4
14	60	160	43.7	17.5
14	60	170	41.6	15.6
14	0	140	52.3	25.6
14	30	140	51.4	24.7
14	90	140	49.2	20.2

pulp yield gain was 6.4% with similar kappa number in soda-AQ process. Same results were obtained if cooking time is reduced by 30 min with no change of alkali charge.

Strength properties

Figs. 2-4 show the strength properties of soda-AQ pulps from corn stalks. Before beating, the breaking length was 3915m and 4512m for soda and soda-AQ pulps respectively which increased to 7702m and 7891m on beating. Soda-AQ pulp showed better breaking length than that of soda pulp (Fig. 2), suggesting that interfibre bonding strength is higher in soda-AQ pulp. As shown in Fig. 3 the burst index of soda-AQ pulp was higher than the soda pulp in the SR number

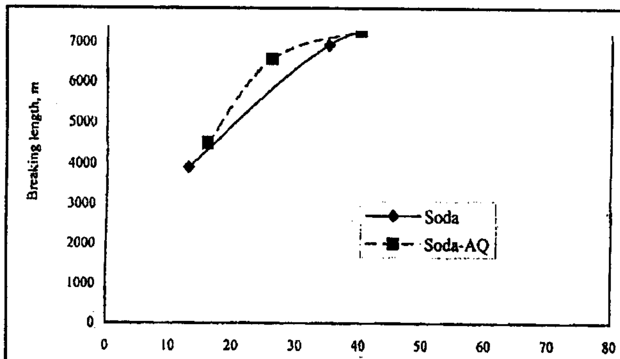

Fig. 1. Effect of AQ on pulp yield and kappa number of corn stalks.

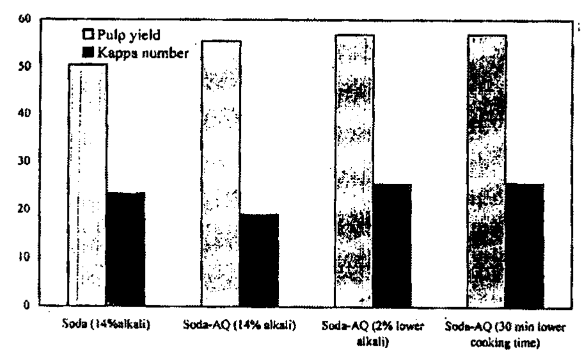

Fig. 2. Freeness Vs Breaking length of soda and soda-AQ pulps

above 20. AT 40°SR, soda-AQ pulp and 1kPa.m^2/g higher burst index. Tear index of both soda and soda-AQ pulps decreased with increasing SR number (Fig. 4). At any SR Number soda-AQ pulp exhibited lower tear index than soda pulp. At 40°SR, 36% lower tear index was observed in soda-AQ pulp. This result was well in accordance with other investigation (10).

Kraft and Kraft-AQ process

Pulp yield and kappa number

One set of experiments was performed in kraft process with varying active alkali and sulphidity. The temperature was kept constant at 140°C. Active alkali vs. kappa number is plotted in Fig. 5. At a fixed sulphidity, kappa number decreased

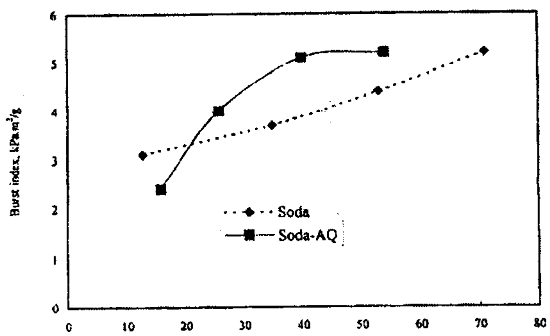

Fig. 3. Freeness Vs Burst index of soda and soda-AQ pulp.

with active alkali. The kappa number was decreased by 16, 14 and 13% with increasing active alkali from 12 to 16% at 11, 19 and 30% sulphidity respectively.

Fig. 6 shows the effect of active alkali and sulphidity on pulp yield of corn stalks. Pulp yield was increased with decreasing active alkali and increasing sulphidity. At 14% active alkali, pulp yield was increased to 51.1% from 48.6% with an increase of sulphidity from 11% to 30%. Effects of AQ in low and high sulphidity kraft pulping of corn stalks is shown in Fig. 7. Addition of AQ in kraft liquor increased pulp yield and decreased kappa number as expected.

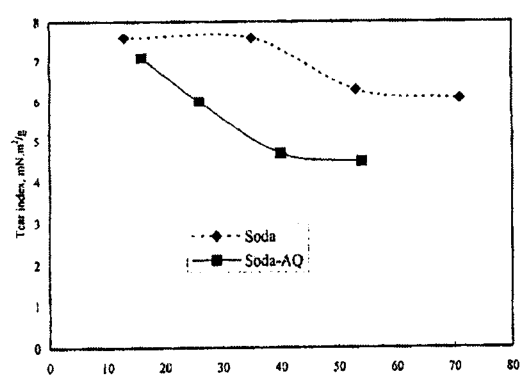

Fig. 4. Freeness Vs Tear index of soda and soda-AQ pulps.

AQ was more effective in low sulphidity kraft pulping than high sulphidity. An addition of 0.05% AQ in kraft liquor increased pulp yield by 7.1 and4.5% on o.d. corn stalks and reduced kappa number by 4.5 and 3.6 points in low and high sulphidity kraft pulping respectively. These results are in good accordance with our earlier investigation of Muli bamboo (11) and sapwood pulping (12).

Strength properties

Figs. 8-10 show the effect of sulphidity on the physical properties of kraft pulps from corn stalks. It is clearly seen that sulphidity did not influence significantly in the development of strength properties. Little increase of strength was observed at high sulphidity. Addition of AQ in the low sulphidity kraft liquor pulp produced,

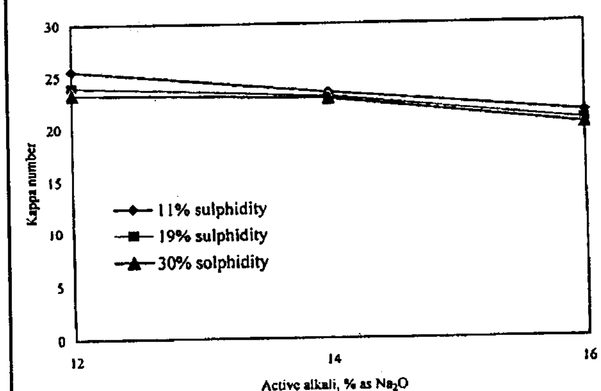

Fig. 5. Effect of active alkali and sulphidity on the delignification of corn stalks.

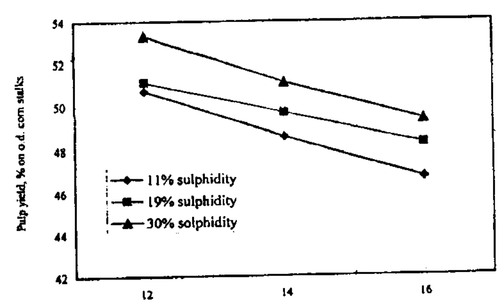

Fig. 6. Effect of active alkali and sulphidity on pulp yield of corn stalks.

showed slightly higher breaking length. The effect of AQ on the breaking length in the high sulphidity kraft pulping was not promising as low sulphidity kraft pulping (Fig. 8). At 40°SR, AQ increased breaking length 14% by in low sulphidity kraft process. Similar results were observed in case of burst index (Fig.9).

Fig. 10 shows the relationship between ^{0}SR number and tear index of kraft and kraft-AQ pulps. Tear index exhibited of all pulps decreased with increasing SR number. Low sulphidity kraft pulp exhibited of all pulps decreased with increasing SR number. Low sulphidity kraft pulp exhibited lower tear index at any ^{0}SR. Tear index was increased with increasing sulphidity. Pulp produced in low sulphidity kraft-AQ showed 22% higher tear index than the L-kraft pulp but high sulphidity kraft-AQ pulp showed slightly lower tear index than the kraft pulp.

Table 2 shows the comparison of corn stalks pulps produced in the soda-AQ, high sulphidity kraft and low sulphidity kraft-AQ processes and also compares these pulps with bamboo (11) and mixed hardwood pulps (13) in kraft process. It is clearly seen that the pulp yield of corn stalks from soda-AQ and L-kraft-AQ processes was higher than the high sulphidity kraft process. The kappa number of AQ used pulps was about 2.5 points lower as compared to kraft high process. Corn stalks from all processes were higher in yield and lower in kappa number than the bamboo and bagasse pulp. The breaking length of kraft and kraft-AQ pulps was better than that of soda-AQ pulp but all these corn stalks pulps showed higher value than the bamboo pulp. The mixed hardwood pulp exhibited higher breaking length than any other pulps. The tear index of kraft and kraft-AQ pulp from corn stalks was better than the soda-AQ pulp but much inferior than that of bamboo and mixed hardwood pulps.

According to Gurangal et al (14), fibre strength is directly proportional to α-cellulose content for fibres of low fabril angle and pulped by processes that do not degrade cellulose. Furthermore, the loss of fibre strength at high α-cellulose contents is due to the degradation of cellulose, which in turn is a result of the localized (heterogeneous) degradation rather than the randomly homogenous degradation rather than the randomly homogenous degradation. Earlier reserach has shown that during kraft cooking the paracrystalline cellulose regions are transformed into a fabril with altering order and amorphous regioin (15). Research has also shown that amorphous regions are able to absorb energy when the fibre is under mechanical stress and thereby contribute to the greater of kraft pulp as compared to sulphite or soda pulp, which

Table 2. Comparison of corn stalks pulps with bamboo and mixed hardwood (strength properties were measured at about 40^{0}SR).

	Corn stalks pulp			Bamboo	Mix hardwood
	Soda-AQ	Kraft-high	L-Kraft-AQ		
Pulp yield, %	55.5	51.1	55.7	45.9	45.5
Kappa number	19.0	22.7	18.8	24.6	45.0
Breaking length, m	7307	7812	7809	5511	8600
Burst index, kPa.m2/g	5.1	4.4	4.3	4.9	6.3
Tear index, mN.m2/g	4.7	6.6	6.2	18.1	10.5

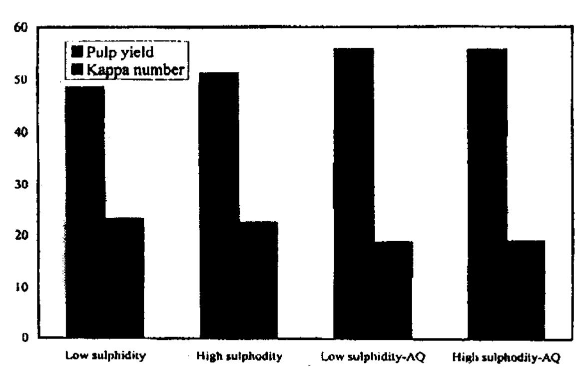

Fig. 7. Effect of sulphidity and AQ on pulp yield and kappa number in corn stalks pulping.

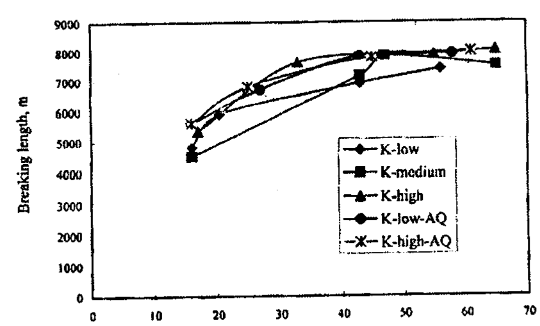

Fig. 8. Freeness Vs breaking length of kraft pulps.

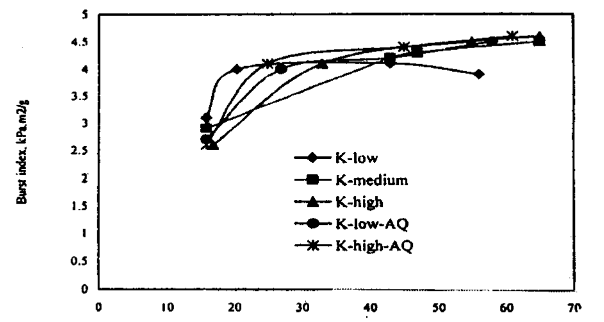

Fig. 9. Freeness Vs burst index of kraft pulps.

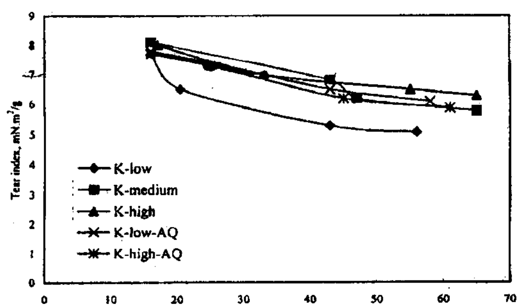

Fig. 10. Freeness Vs tear index of kraft pulps.

contains fewer amorphous regions (16).

CONCLUSION

The following conclusions may be drawn from this investigation: In the optimum conditions of soda process, corn stalks showed pulp yield of 50.5% with kappa number 23.4. An addition of 0.05% AQ in the soda liqour raised to 55.5% and kappa number reduced to 19.0. In the kraft process, pulp yield increased with increasing sulphidity and decreasing active alkali. Pulp yield increased and kappa number decreased on addition of 0.05% AQ in the kraft liquor. The effectiveness of AQ was more pronounced in low sulphidity kraft process. Soda-AQ process showed higher breaking length and burst index and inferior tear index than the soda process. High sulphidity process produced pulp of better strength properties than the low sulphidity but addition of 0.05% AQ in the low sulphidity kraft liquor, strength properties improved to in sulphidity kraft pulp. Therefore, effectiveness of AQ was pronounced in the low sulphidity kraft process. Pulp yield, kappa number and breaking length of corn stalks pulps were better and tear index was inferior to bamboo and mixed hardwood pulps.

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