Nonwood pulping: use of jute cuttings and caddis in Bangladesh

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ABSTRACT: Utilization of jute cutting and caddis is of social and economic importance in Bangladesh. In this study, soda-anthraquinone, alkaline sulfite-anthraquinone, and neutral sulfite-anthraquinone processes were evaluated for jute-cutting and caddis pulping. The NS-AQ process showed favorable pulp yield and kappa number for both of these raw materials: 66.1% for jute cuttings and 59.9% for caddis at kappa no. 11. The physical properties of NS-AQ pulps were also better than those of soda-AQ and AS-AQ pulps. At ^{0}SR 44, the tensile index of NS-AQ pulp was about 100 N.m/g for jute cutting and 70 N.m/g for caddis, and the tear index was similar. All pulps were bleached by $D_0E_pD_1$ bleaching sequences. The NS-AQ pulp showed excellent bleachability. Its brightness reached 89.0% for jute cuttings and 85.0% for caddis using total chlorine dioxide of about 15 kg/ton. After bleaching, the strength properties of NS-AQ pulp were slightly better compared to soda-AQ and AS-AQ pulps.

Application: The results can help mill management make decisions about a suitable pulping process for jute fiber and help engineers and technologists design equipment for the process.

The vast majority of pulp, including viscose pulp and other cellulose grades, is produced from wood, which mostly comes from forests. Forest-deficient countries like Bangladesh, which also has high population density, have strong economic and social motivation to utilize cellulose fibers from annual plants or short-rotation trees [1].

Nonwood fiber is an important source for papermaking in many developing countries. Some nonwood plants can give more pulp per hectare per year than wood [2]. Jute is one of the most important natural fibers in Bangladesh and has a long historical role in the socioeconomic development of the country. Once known as the "golden fiber of Bangladesh," jute and related products account for a significant portion of total exports. In addition, jute provides considerable employment opportunities for the country's workforce. Chemical and morphological characteristics such as fiber length, α-cellulose, and lignin are indications that jute is an excellent pulping raw material [3]. Utilization of jute in pulp production may create a new horizon for farmers in Bangladesh. To this aim, many studies have been done on the pulping of jute domestically and abroad [4–10]. Akhtaruzzaman and Shafi [4] claimed that the neutral sulfite-anthraquinone (NS-AQ) process is a suitable process for jute fiber pulping, which led to the production of pulps similar to those from softwood. Jahan and Farouqui [11] showed that the addition of amine to the soda pulping process increased the pulp yield and delignification rate, with physical properties of the pulp produced similar to those of coniferous pulp. Soda-anthraquinone (soda-AQ) pulp from jute fiber was superior to softwood kraft pulp [5]. The jute pulp from an alkaline sulfite anthraquinone methanol (ASAM) process had excellent strength properties and bleachability [5].

However, the price of jute fiber cannot compete with wood as the pulping raw material. In Bangladesh, many jute textile mills are producing jute fiber products such as bags, fabric, and ropes. In such operations, the bottom part of the jute is not used because of inferior properties; this is removed in the mill and is commonly known as jute cuttings. Jute caddis, obtained as rejects in the jute mill, is another underused material. Roughly, jute cuttings would account for 15% and caddis would account for 3% of the available jute fibers (**Table I**). There are strong economic and social incentives to make value-added products from the jute cuttings and cad-

	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010
Production	810	990	990	990	931	1,086
Mill consumption	522	504	486	468	617	650
Cutting	78.30	75.60	72.9	70.2	92.67	97.50
Caddis	13.05	12.6	12.15	11.70	15.45	16.25
Jute stick	2,025	2,475	2,475	2,475	2,327.5	2,700.75
Export	306.60	440.50	438.30	495.50	314.90	315
Closing stock	0	0	20	1.50	6.30	61.30

I. Production and consumption of jute in Bangladesh (1,000 metric tons).

dis. Bangladesh imports about 250000 metric tons of pulp and paper products, which costs about USD 300 million.

Table I shows the jute production and consumption in Bangladesh. Consumption in the mills showed a steady increase with the exception of the period 2005–2007. A greater increase in mill consumption obviously produced more jute cuttings and caddis as mill wastes. There were still 61300 metric tons of jute fiber left over in 2009–2010; thus, a total of 175050 metric tons of jute, including cuttings and wastes (jute cuttings 97500 metric tons + jute 61300 metric tons + caddis 16250 metric tons) was available for diversified use in 2009–2010. One way of utilizing jute is to produce cellulose pulp, which can then reduce the country's dependency on imported long-fiber pulp [8]. Jute cuttings and caddis were shown to have good fiber characteristics, similar to softwood [3].

Jute and its related businesses are of economic significance to many people in Bangladesh, particularly the jute farmers. Extracting greater value for jute crops, thus maximizing profit for the jute farmers, has been the agenda of the Government of Bangladesh. Recently, the North Bengal Pulp and Paper Mills (NBPM) was reopened; it had been shut down because of the shortage of raw materials. The unused jute fiber and other jute mill wastes, including jute cuttings and jute caddis, would be good raw material for NBPM. In this context, Bangladesh Jute Mills Corporation (BJMC) signed an agreement with China's Yunan Engineering Corporation for technical evaluation.

The variation of results on jute pulping was observed in the literature. Research on pulping of retted jute bast fiber was initiated in 1966 [12]. The author claimed that conventional soda pulping of the bast fiber gave a high yield (65.7%) at a permanganate number of 7.3 (kappa no. 8.5). Such a high yield in the soda process is in contradiction to the work by Yee [13] and Japan International Cooperation Agency [14], which showed a total yield of 55.4% at kappa no. 20.8 and 58.4% at kappa no. 22.8, respectively. The pulp obtained by Islam [12] was inferior and was comparable to aspen sulfite and other hardwood pulps. Such differences might be due to the different quality of fibers used in the study. Different pulping chemical processes were also evaluated for jute fiber pulping [4-6,9,15-16]. On the basis of the literature, the soda-AQ process was shown to be better suited for jute fiber pulping over the kraft process [5]. It was also observed that the alkaline sulfite-anthraquinone (AS-AQ) process showed higher pulp yield and physical properties than those of the kraft process [6,27]. The NS-AQ process also showed better performance than the soda-AQ and the kraft process, but needs a longer cooking period [4].

As part of the precommercial study and to provide basic data for further engineering and process designs, we carried out a research and development project related to pulping, bleaching, and evaluation of the resulting pulp properties using jute cuttings and caddis. Three pulping processes, namely NS-AQ, AS-AQ, and soda-AQ were performed. Bleaching of these pulps was also carried out in an ECF bleaching sequence of $D_0E_pD_1$ and pulp properties were evaluated.

MATERIAL AND METHODS

Materials

Jute cuttings and caddis were collected from a jute mill in Narayangong, Bangladesh. These were chopped to 2–3 cm in length for subsequent cooking experiments. The α-cellulose, klason lignin, pentosan, and diclorometháne extracts of jute cutting and caddis were 60.0% and 58.6%, 14.0% and 14.7%, 14.1% and 14.0%, and 0.43% and 3.86%, respectively [3].

Pulping

All pulping was done in a 20-L capacity, thermostatically controlled, electrically heated rotary digester. All experiments were carried out in triplicate. The chemical charge was based on the literature, as given in **Table II**. The chemical charge was expressed as sodium hydroxide (NaOH) on o.d. raw material. In the NS-AQ process, the sodium sulfite (Na_2SO_3)-to-sodium carbonate (Na_2CO_3) ratio was 0.83. The chemical charge was 18.0% on o.d. raw material. The liquor-to-fiber ratio was 5:1 and the AQ charge was 0.1% on o.d. raw material. In this process, cooking time was 180 min at 170°C.

In the AS-AQ process, total chemical charge was 16.0% and AQ was 0.1% on o.d. raw materials. The cooking time was 90 min at 170°C, and the liquor-to-fiber ratio was 5:1. The time required to raise the maximum temperature from the room temperature was 60 min.

Raw Materials	Process	NaOH or Na_2CO_3* (Expressed as NaOH on O.D. Raw Material)	Na_2SO_3 (Expressed as NaOH on O.D. Raw Material)	Cooking Time at 170°C (min)	Pulp Yield (%)	Kappa No.
Jute cutting	Soda-AQ	16	-	90	64.2±0.54	10.7±0.09
	AS-AQ	5.40	12.60	90	65.5±0.61	16.9±0.14
	NS-AQ	3.06*	14.94	180	66.1±0.63	11.1±0.11
Jute caddis	Soda-AQ	16	-	90	54.6±0.45	12.7±0.14
	AS-AQ	5.40	12.60	90	59.2±0.51	18.5±0.26
	NS-AQ	3.06*	14.94	180	59.9±0.54	12.3±0.21

II. Pulping results of jute cuttings and caddis in soda-AQ, AS-AQ, and NS-AQ processes.

In the soda-AQ process, the alkali charge was 16.0% and AQ was 0.1% on o.d. raw materials. The cooking was continued for 90 min at the maximum temperature (170°C).

At the end of pulping, the pressure was relieved to atmospheric pressure. The pulp was taken out from the digester, disintegrated and washed by continuous flow of water and screened by a flat vibratory screener (Yasuda Corporation; Toyohashi, Japan). There was no pulp reject in these pulps. Pulp yield was determined as dry matter obtained on the basis of o.d. raw material. Kappa number was determined in accordance with TAPPI Standard Test Method T 236 cm-85 "Kappa number of pulp."

Bleaching

The pulps were bleached by $D_oE_pD_1$ bleaching sequences. The chlorine dioxide (ClO_2) charge was 1.0% and temperature was 70°C for 60 min in the D_0 stage. The pH was adjusted to 2.5 by adding dilute sulfuric acid (H_2SO_4). In the alkaline extraction stage, temperature was 70°C for 60 min with NaOH and hydrogen peroxide charge of 2.0% and 0.5%, respectively. In the final D_1 stage, pH was adjusted to 4 by adding dilute H_2SO_4.

All pulps were beaten in a PFI mill to different revolutions. Handsheets of about 60g/m² were made in a Rapid-Köthen sheet former (Karl Kolb; Dreieich, Germany) according to German Standard Methods DIN 106. The sheets were tested using TAPPI Standard Test Methods for tensile (T 494 om-96 "Tensile properties of paper and paperboard [using constant rate of elongation apparatus]"), burst (T 403 om-97 "Bursting strength of paper"), and tear strength (T 414 om-98 "Internal tearing resistance of paper [Elmendorf-type method]"). The strength properties of bleached pulps were determined according to TAPPI Test Methods the same as specified previously for unbleached pulps.

RESULTS AND DISCUSSION

Pulp yield and kappa number

To evaluate the different processes for jute pulping, soda-AQ, AS-AQ, and NS-AQ pulping of jute cutting and jute caddis were carried out under optimum conditions based on literature. The results are shown in Table II. The pulp yield of the NS-AQ process was the highest among these three processes—66.1% for jute cuttings and 59.9% for caddis. The lower pulp yield for caddis is due to lower α-cellulose and higher impurities and foreign materials [3]. In an earlier study, Shafi et al. [8] obtained a total pulp yield of 64.4% at kappa no. 20 for whole-length jute fiber by the NS-AQ process. Akhtaruzzaman and Shafi [4] claimed the NS-AQ process gives superior pulp yield over other processes for jute pulping. The pulp yield of jute fiber in the soda-AQ process was 51.0%–57.0% at different alkali charges [14].

For jute cuttings, the kappa number in the soda-AQ and NS-AQ processes was almost similar at about 11, which was 6 points lower than for the AS-AQ process (Table II). Caddis pulp exhibited slightly higher kappa number than the corresponding jute cutting pulp. The dichloromethane extractive in jute caddis was higher (3.86%), which was due to the material being treated with oil for jute softening [3]. The presence of oil might hinder delignification. Shahin and Young [9] obtained pulp with kappa no. 42 from jute fiber in the acetosolv process. The formic acid pulping process, followed by peroxyformic acid bleaching, produced pulp with kappa no. 8 and pulp yield of 60.0% [17]. These results for pulp yield and kappa number of jute were better than those obtained from hardwoods [18]. They can be explained by the differences in the chemistry of these raw materials: lower lignin content (12.7%) [3] and higher syringyl-to-guaiacyl ratio (2.1) [19] for the jute fibers.

On the basis of the above results, it was concluded that the

	Soda-AQ				NS-AQ				AS-AQ			
	°SR	Tensile Index	Burst Index	Tear Index	°SR	Tensile Index	Burst Index	Tear Index	°SR	Tensile Index	Burst Index	Tear Index
Jute cutting	14	15.7	1.7	8.4	8	22.9	2.0	9.5	13	18.4	1.8	9.2
	19	29.6	2.6	15.7	21	59.3	4.9	19.3	20	42.5	3.2	18.6
	31	53.1	5.5	21.2	24	73.7	6.6	23.9	31	53.5	6.3	20.2
	43	82.5	5.5	16.2	40	88.4	7.9	16.4	45	70.7	7.1	16.0
	61	83.1	5.3	15.3	69	104.2	9.2	15.1	62	75.2	7.2	15.3
Caddis	16	5.4	1.3	6.5	16	9.1	1.4	6.5	16	13.2	1.8	9.0
	28	40.2	2.5	13.6	25	46.7	3.8	16.2	25	42.9	3.7	15.4
	43	48.6	2.8	13.3	44	59.1	4.9	15.8	44	60.7	5.0	15.6
	68	56.0	3.8	11.7	62	72.5	5.2	15.7	66	62.3	5.1	15.3

III. Physical properties of jute-cutting and caddis pulps obtained from soda-AQ, AS-AQ, and NS-AQ processes

NS-AQ process is the most suitable for pulping jute cuttings and caddis because it gave a high pulp yield and low kappa number.

Physical properties of unbleached pulp

Pulps obtained from different processes were beaten in a valley beater, and handsheets were prepared for physical testing. As shown in **Table III**, the NS-AQ pulp from jute cuttings showed superior tensile development over AS-AQ and soda-AQ processes; that is, at ^{0}SR 40, the tensile index of NS-AQ pulp was 10.0% and 25.0% higher than AS-AQ and soda-AQ pulps, respectively. Similarly, the tensile index of NS-AQ pulp from caddis was 14.0% and 40.0% higher than the AS-AQ and soda-AQ pulps, respectively at ^{0}SR 40. The burst index of jute-cutting pulp in the NS-AQ process was also higher than AS-AQ and soda-AQ pulps at any ^{0}SR (Table III). At ^{0}SR 40, the burst index of NS-AQ pulp from jute cuttings was 13.0% and 43.0% higher than the corresponding AS-AQ and soda-AQ pulps.

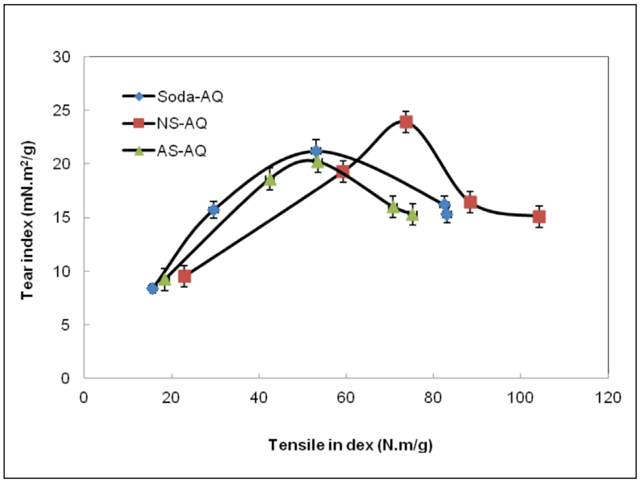
The tear index of jute cutting and caddis pulps increased with increasing ^{0}SR and then decreased (Table III). The maximum tear index (23.9 mNm^2/g) of jute-cutting pulp was obtained at ^{0}SR 24; for caddis it was 16.2 mNm^2/g at ^{0}SR 25 for the NS-AQ pulp. Caddis pulps from the AS-AQ and NS-AQ processes had similar tear index at ^{0}SR 44, which was 17.0% higher than pulp from the soda-AQ process.

From the papermaker's point of view, tear-tensile relationship is of practical importance. **Figures 1** and **2** show a favorable tensile-tear relationship for the NS-AQ jute-cutting pulp in comparison with the AS-AQ and soda-AQ processes at a high ^{0}SR. For caddis pulp, the AS-AQ pulp showed better tear-tensile relationship than the other two processes. At tensile index 60 N.m/g, AS-AQ and NS-AQ pulps showed an almost similar tear index (15.7 mN.m^2/g). The strength results obtained from the soda-AQ, NS-AQ, and AS-AQ processes in this study are better than those in the literature that were obtained from solvent pulping processes [6,9,20].

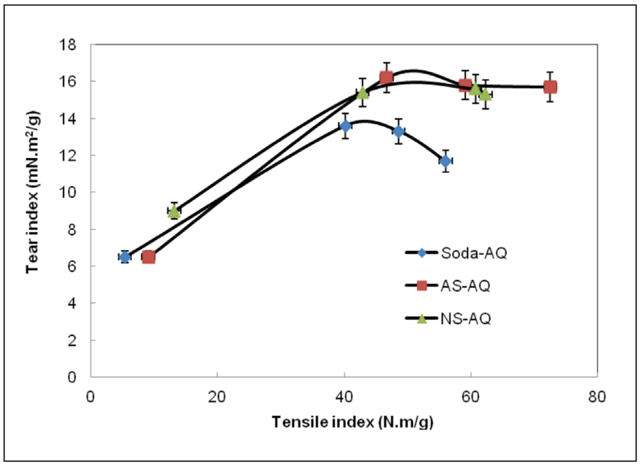
On the basis of the strength properties discussed previously, it was concluded that the NS-AQ process is the most favorable among all those studied.

Bleaching

Pulps obtained from jute cuttings and caddis in soda-AQ, AS-AQ, and NS-AQ processes were bleached using $D_0E_pD_1$ bleaching sequences with a total ClO_2 charge of 15 kg/ton of pulp. According to the literature, jute pulp shows good bleachability in both elemental chlorine free (ECF) and total chlorine free bleaching [3,21]. The overall yield for jute cuttings was still above 60.0%. Among these three processes, NS-AQ yielded the highest overall pulp yield (61.3%) for jute cuttings (**Table IV**). The bleached yield for caddis was 47.0%–50.0%, which was similar to or higher than for wood [22] and other nonwood fibers [23–24]. A good pulp brightness was obtained, in particular for the NS-AQ pulps: 89.4% for jute cutting and 85.7% for jute caddis. The caddis pulps in the AS-AQ and soda-AQ processes showed poor bleachability, which may be due to the high content of mineral oil. After bleaching, strength properties of NS-AQ pulps were slightly better compared with soda-AQ and AS-AQ pulps. The same tendency was observed by Akhtaruzzaman et al. [15]. The opacity of caddis pulp is slightly higher than the corresponding jute-cutting pulp, which is due to the lower brightness.



1. Tensile-tear relationship of jute-cutting pulps obtained in different processes.



2. Tensile-tear relationship of jute-caddis pulps obtained in different processes.

Supply and storage

The raw material supply and its transportation and storage would be critical for a commercial jute-based pulp mill. Jute is a seasonal crop and is cultivated by farmers in different localities. Jute is mainly grown for the retted bast fiber, which brings immediate cash to the farmers during the lean period. In extracting the bast fiber on retting, the woody core is obtained as the by-product. This core is largely used by villagers as fuel, in making thatched houses, or for fencing. Although the value of the core is less than the bast fiber, alternative uses of jute stems or cores may help to address social problems in the rural areas where fuel wood and thatching materials are

	Soda-AQ		AS-AQ		NS-AQ	
	Cutting	Caddis	Cutting	Caddis	Cutting	Caddis
Bleached yield (%)	93.9	86.6	91.9	83.9	92.8	80.7
Overall yield (%)	60.3	47.3	60.2	49.7	61.3	48.3
^{0}SR after 1500 PFI rev.	25	30	24	31	25	29
Tensile index (N.m/g)	39.2	32.8	37.7	36.9	37.1	36.8
Tear index (mN.m^2/g)	18.7	13.7	20.0	15.2	21.7	15.5
Burst index (kPa.m^2/g)	3.4	3.2	4.1	3.6	4.1	4.0
Brightness (%)	81.1	73.3	82.3	74.5	89.4	85.7
Opacity (%)	93.9	90.0	89.2	89.6	89.3	89.8

IV. Bleaching results of soda-AQ, NS-AQ, and AS-AQ pulps from jute cuttings and caddis.

scarce. Jute stem is susceptible to fungal attack and is difficult to store due to its bulkiness [25]. The situation is entirely different when the bast fiber is considered; the density of the retted bast fiber is 1.5 g/cm^3 [26] compared with 0.185 g/cm^3 for the stem [27]. This means there is a large advantage in transportation and storage of the bast fiber. Also, the dried fiber is resistant to microorganisms and insects [26].

The collection and transportation of retted jute bast fiber are well accepted by the jute fabric mills. The farmers bring the dried material in hand-pressed bundles to the selling centers or markets. The practice continues for months after harvesting. The jute cuttings and caddis are produced in the mills, which mostly belong to the BJMC. These mills have good facilities for storage of jute and jute wastes; therefore, the storage of jute bast fiber, jute cuttings, and caddis as the raw materials for a potential pulp mill is already well established.

CONCLUSIONS

In Bangladesh, jute fiber and jute mill wastes may be an important raw material for pulp and paper. This study is part of a large project initiated by the Government of Bangladesh. Soda-AQ, AS-AQ, and NS-AQ pulping processes of jute cuttings and caddis, and subsequent ECF bleaching, were evaluated. It was found that the NS-AQ process exhibited the best results in respect to pulp yield, delignification, physical properties, and bleachability. Jute-cutting pulp showed better results compared to jute caddis for a given process: a 66.0% pulp yield from jute cutting at kappa no. 11, which is much higher than that from wood; the tear index of 23 mN.m^2/g at the tensile index of 73 N.m/g; and a final brightness of 89.0% in an ECF bleaching sequence of $D_0E_pD_1$, with a total of 15kg ClO_2/metric ton of pulp. On the basis of these results, it was recommended to follow an NS-AQ process for processing jute cuttings and caddis for a potential jute pulp mill in Bangladesh. **TJ**

LITERATURE CITED

1. Jahan, M.S., Chowdhury, D.A.N., and Ni, Y., *Bioresour. Technol.* 101: 1892(2010).
2. Pahkala, K.S., "Non-wood plants as raw material for pulp and paper," Ph.D. dissertation, Helsinki University, Helsinki, Finland, 2001.
3. Jahan, M.S., Maruf, A.A., and Quaiyyum, M.A., *Bangladesh J. Sci. Ind. Res.* 42(4): 425(2007).
4. Akhtaruzzaman, A.F.M. and Shafi, M., *Tappi J.* 78(2): 106(1995).
5. Jahan, M.S., *TAPPI J.* 84(8): 1(2001).
6. Jahan, M.S., Chowdhury, D.A.N., and Islam, M.K., *Ippta J.* 17(2): 37(2005).
7. Roy, T.K., Mohindru, V.K., Behera, N.C., et al., *Ippta J.* 10(3): 81(1998).
8. Shafi, M., Akhtaruzzaman, A.F.M., and Mian, A.J., *Holzforschung* 47(1): 83(1993).
9. Sahin, T.H. and Young, R.A., *Ind. Crops Prod.* 28(1): 24(2008).
10. Bose, S.K., Akhtaruzzaman, A.M.F., and Khan, H.R., *TAPPI J.* 82(5): 148(1999).
11. Jahan, M.S. and Farouqui, F.I., *Holzforschung* 54(6): 625(2000).
12. Islam, M.A., *Sci. Res.* 3(3): 151(1966).
13. Yee, T.T., *Trop. Sci.* 26(3): 173(1986).
14. "A study on the utilization of jute cuttings/lower graded jute for papermaking," Task Force Report, Ministry of Jute, Government of the People's Republic of Bangladesh, Dhaka, 1988.
15. Akhtaruzzaman, A.F.M., Siddique, A.B., Bose, S.K., et al., *Nonwood Plant Fiber Progress Report* No. 19, TAPPI Press, Atlanta, GA, USA, 1991, pp. 123–132.
16. Roy, A.K. and Chattopadhaya, S.N., *Ippta J.* 14(3): 121(2012).
17. Jahan, M.S, Chowdhury, D.A.N., Islam, M.K., et al., *Cellul. Chem. Technol.* 41(2–3): 137(2007).
18. Parthasarathy, V.R., Smith, G.C., Rudie, F., et al., *Tappi J.* 78(2): 113(1995).
19. Islam, A. and Sarkanen, K.V., *Holzforschung* 47(2): 123(1993).

20. Jahan, M.S., Chowdhury, D.A.N., and Islam, M.K., *Ippta J.* 19(2): 115(2007).
21. Jahan, M.S., Ni, Y., and He, Z., *BioResources* 5(2): 870(2010).
22. Jahan, M.S., Rahman, M.M., Nuruddin, M., et al., *Indian J. Ecol.* 38: 35(2011).
23. Jimenez, L., Torre, M., Maestre, J., et al., *Holzforschung* 52(2): 191(1998).
24. Cordeiro, N., Belgacem, M.N., Tores, I.C., et al., *Ind. Crops Prod.* 19(2): 147(2004).
25. Akhtaruzzaman, A.F.M., "Strategies for jute pulping," *TAPPI Pulping Conf., [Proc.]*, TAPPI Press, Atlanta, 1998, p. 1.
26. Joseph, M.L., *Essentials of Textiles*, 2nd edn., Holt, Rinehart and Winston, New York, 1980, p. 44.
27. Islam, M.A. and Khan, M.A., *Bangladesh J. Sci. Ind. Res.* 19(1–4): 119(1984).

ABOUT THE AUTHORS

The Government of Bangladesh is keen to build a pulp mill that uses jute-based raw materials. Much literature is found on jute pulping in different processes, but results are inconsistent. Therefore, we carried out this research for different processes using the same raw material to find out what would be a suitable process for jute pulping for commercialization.

These results support the previously published results of work done by ourselves and others. The soda-AQ and NS-AQ processes are more suitable than the kraft process for jute pulping, and the NS-AQ pulp exhibited higher tensile-tear strength.

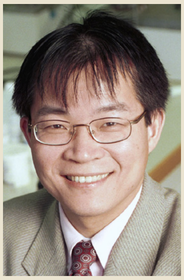
Our main difficulty was observed in getting reproducible data due to the nonhomogeneous character of jute fiber. The morphologies of top, bottom, and middle fibers are quite different. Therefore, we carefully mixed the whole fiber and performed several experiments to get reproducible data.

The NS-AQ process is generally useful for high-yield pulp and in the case of jute fiber, the NS-AQ process behaves differently. Defibration occurs easily, and the pulp shows higher strength and good bleachability.

Mills can use these data to select a suitable process for jute pulping. A pilot study of jute pulping should be carried out to commercialize the process.


Jahan


Rahman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