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Dissolving pulp from jute wastes

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ABSTRACT

Bangladesh Government is interested to produce rayon from jute fiber. But jute fiber is an expensive raw material. Jute cuttings (JC) and jute caddis (CD) are generated as wastes in the jute mill. In this investigation dissolving pulp was produced from low grade jute (LGJ), JC and CD with 90% formic acid (FA) treatment at the boiling temperature for 4 h. JC showed the highest pulp yield (62.3%) and CD showed the lowest pulp yield (58.0%). In this process 12–13% lignin and 25–27% hemicelluloses were also separated from the spent liquor, which can integrate biorefinery. FA pulps were further alkali extracted by varying amount of alkali charge at 25 and 90 °C for 120 min. Alkali extraction reduced kappa number and residual pentosan content in pulp. In the $D_0E_pD_1$ bleaching sequence, brightness of LGJ and JC pulps reached to 83–86% and pulp purity to 96% with fock reactivity of 61–67%.

1. Introduction

The majority of paper grade and dissolving grade pulps are produced from wood, which come from the forest. There is strong economic and social motivation in utilizing cellulose fibers from annual plants or short rotation trees in forest deficient countries, like Bangladesh (Danielewicz et al., 2018, Iglesias et al., 1996, Jahan, 2001, Jahan et al., 2007, a, 2008, 2013a, b). Historically jute is the most important natural fibers in Bangladesh. The chemical and morphological characteristics such as fiber length, α-cellulose and lignin indicated that jute is an excellent pulping raw material (Jahan et al., 2007). Utilization of jute is of social and economic importance in Bangladesh. To achieve this aim, many studies have been carried out on jute pulping of in home and abroad (Akhtaruzzaman and Shafi, 1995, Sahin and Young, 2008, Jahan, 2001, Jahan et al., 2007, a, 2008, 2013a, b). Akhtaruzzaman and Shafi (1995) claimed that 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 et al. (2013a, 2013b) further proved that NS-AQ was best the process for paper grade pulp. Jahan (2001) showed that the addition of amine or quinone to the soda liquor increased the pulp yield and delignification rate, while the physical properties of produced pulp were similar to coniferous pulp. The jute pulp from an alkaline sulfite anthraquinone methanol (ASAM) process had excellent strength properties and bleachability (Jahan et al., 2005).

Jahan et al. (2007b) studied jute delignification by acetic acid (AA), formic acid (FA) and peroxyformic acid in an atmospheric condition. Acetic acid could not delignify jute fiber without HCl catalyst, while formic acid could do. Produced pulp easily bleached to 81.5% brightness in two stage alkaline peroxide bleaching. Residual pentosan in organic acid pulp was very low, which indicated the suitability of this process in producing dissolving pulp. In another study dissolving pulp was produced from jute fiber, jute cutting and jute caddis by formic acid followed by peroxyformic acid and finally pulp were bleached by two stages alkaline peroxide bleaching (Jahan et al., 2008). The α-cellulose content was 93–98% with a high pulp viscosity and a good brightness (81–87%). But in that study, reactivity, residual hemicelluloses were not mentioned.

Nayeem et al. (2017) fractionated pre-hydrolysed kraft pulp from jute into short, medium and long fiber in order to improve purity and reactivity. Fock reactivity increased with decreasing fiber size, but α–cellulose content in long fiber fraction was higher than that of short fiber fraction. Alkaline extraction fractionated jute pulp removed pentosan consequently increased α-cellulose content in the pulp. Fock's reactivity also increased after reduction of hemicelluloses by weak alkaline extraction. In that study, it was also shown that formic acid treatment followed by alkaline extraction and DE_pD bleaching produced pulp of 94.3% purity with Fock's reactivity of 63.2%. Alkaline extraction of the pulp increased purity to 97% with Fock's reactivity of 72–73%.

Recently Bangladesh Government shows interest to produce rayon from jute fiber. Presently, rayon is being produced from wood. But the price of jute fiber cannot complete with wood. The price of jute fiber is around Tk50000 per ton, whereas of the same of jute cutting and caddis

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is about Tk40000 and Tk5000, respectively (BJMC, 2018). In Bangladesh, about 100,000 MT jute cuttings and 16,000 MT of jute caddis are produced each year (Jahan et al., 2013a, 2013b). In order to reduce raw material cost, jute cutting and caddis can be used for dissolving pulp production (Jahan et al., 2007). The amounts of raw materials are not sufficient to make conventional prehydrolysis kraft process to make a viable pulp mill for rayon production. Now it is well established that organic acid process is suitable for dissolving pulp production and FA dissolve lignin and hemicelluloses simultaneous (Jahan et al., 2007b, 2008). But these studies used FA treatment followed peroxyformic acid delignification to get dissolving grade pulp, which was bleached by alkaline peroxide bleaching. For the first time in this study, jute wastes are used for FA treatment followed by alkaline extraction to remove maximum hemicelluloses and lignin from the pulp.

Therefore, in this investigation dissolving pulp was prepared from jute cutting (JC) and jute caddis (CD) by formic acid (FA) process followed by alkaline extraction of the FA treated pulp to remove lignin and hemicelluloses further and compared the results with low grade jute (LGJ). Alkaline extracted pulp was bleached by $D_0E_pD_1$ bleaching sequences. Bleached and unbleached pulps were evaluated in terms of viscosity, purity and reactivity.

2. Material and methods

Low grade jute, jute cutting and jute caddis were collected from the Bangladesh Jute Mills Corporation (BJMC). The lignin, α-cellulose and pentosan content in jute, jute cutting and jute caddis were, 12.7, 14.0 and 14.7%, 63.1, 60.0 and 58.6% and 13.5, 14.1 and 14.0%, respectively (Jahan et al., 2007).

2.1. Formic acid pulping

The low grade jute, jute cutting and jute caddis was refluxed with 90% formic acid water mixture in a hotplate under the following different conditions:

- Reaction time: 4 h at boiling 107 °C.
- Material to liquor ratio: 1:8.

After desired reaction time, pulp was filtered in a buckner funnel and washed with fresh formic acid- water followed by hot distilled water. Then the pulp yield was determined gravimetrically and kappa number (T 236 om 99) and pentosan (T223 cm 01) was determined by Tappi Test Methods.

2.2. Alkaline extraction

Alkaline extraction of formic acid bleached pulps was carried out with 8, 10 and 12% sodium hydroxide (based on pulp) at 25 and 90 °C for 2 h. The consistency was 10%. After extraction, pulp was filtered in a buckner funnel and washed with fresh distilled water. The pulp yield was determined gravimetrically and pentosan (T223 cm 01) was determined by Tappi Test Methods.

2.3. Analysis of FA and alkaline extracted liquor

The total solid content in the alkaline extracted liquor was determined gravimetrically by drying 50 ml sample at 105 °C to constant weight. Ash content in the alkaline extracted liquor was determined following TAPPI Standard Methods T 211 om02.

2.4. Bleaching

Alkaline extracted pulp was bleached by conventional $D_0E_pD_1$ bleaching sequences. D_0, D_1 and E_p denoted chlorine dioxide in the first stage, chlorine dioxide in the 2nd stage and peroxide reinforced alkaline extraction, respectively. The ClO_2 charge was 1% and temperature was 70 °C for 45 min in the D_0 stage. The pH was adjusted to 2.5 by adding dilute H_2SO_4. Alkaline extraction was carried out with 2% NaOH and 0.5%, H_2O_2 charge, temperature was 70 °C for 120 min. In the D_1 stage, ClO_2 charge was 0.5, initial pH was adjusted to 12.0 by adding dilute alkali and final pH reached to 4.5, respectively. The pulp consistency was 10% in all stages.

2.5. Evaluation of pulps

Pulp tests were performed according to the Standard Methods of the Technical Association of the Pulp and Paper Industry (TAPPI, Atlanta, GA): brightness (T 452 om-92); viscosity (T 230 om-89); α-cellulose (T 203 om-88); and alkali solubility S_{10} and S_{18} (T 235 cm-85). Alpha-cellulose is the pulp fraction resistant to a treatment in an aqueous solution containing 17.5% sodium hydroxide and indicates undegraded, high molecular weight cellulose content in pulp. Alkali solubilities S_{10} and S_{18} provide information on the low molecular weight carbohydrates (degraded cellulose and hemicellulose) in pulp. A 10% sodium hydroxide solution dissolves both degraded cellulose and hemicellulose (S_{10}) whereas hemicellulose is soluble in an 18% sodium hydroxide solution (S_{18}). All pulp properties were analyzed in duplicate.

3. Results and discussion

3.1. Formic acid treatment

Jute cutting, low grade jute and jute caddis were cooked by 90% (v/v) formic acid for 4 h at boiling temperature (107 °C). From our previous study it was observed that lignocellulose was not sufficiently delignified when the formic acid concentration was limited to 70%; even longer cooking time (Jahan et al., 2007b). The pronounced effect of delignification was observed in case of formic acid concentration. It is well established that formic acid dissolved lignin and hemicelluloses simultaneously from the lignocelluloses (Nayeem et al., 2017; Jahan et al., 2007). As shown in Table 1, among these three raw materials, JC showed the highest pulp yield (62.3%) and CD showed the lowest pulp yield (58.0%). The pulp yield is much higher than the jute stick in prehydrolysis kraft process (Matin et al., 2015). The yield was even higher than the wood pulp (Claus et al., 2004; Sixta et al., 2004; Vila et al., 2004). Pulp yields in prehydrolysis kraft process from agricultural wastes like rice straw, wheat straw, mustard stalks and lentil stalks were much lower than the jute wastes in the present study (Jahan et al.,

Table 1
Formic acid treatment of LGJ, JC and CD.

Sample	Pulp yield (%) A	Kappa number	Spent liquor		Mass balance A + B
			Solid content (%) B	Lignin (%)	
JC	62.31 ± 0.67	17.57 ± 0.036	38.30 ± 2.14	11.80 ± 0.02	100.6
LGJ	60.74 ± 2.9	23.10 ± 1.12	40.03 ± 1.58	12.86 ± 0.53	100.8
CD	58.02 ± 0.60	32.22 ± 0.77	36.84 ± 0.68	12.12 ± 0.67	94.2