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Chemical characteristics of ribbon retted jute and its effect on pulping and papermaking properties

M. Sarwar Jahan*, Jannatun Nayeem M. Mostafizur Rahman, Marium Islam, M.A. Quaiyyum[1]

Pulp Paper Research Division, BCSIR Laboratories Dhaka, Dr. Qudrat-i-Khuda Road, Dhaka 1205, Bangladesh

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ABSTRACT

Jute is a cash crop of Bangladesh, which is extracted from jute plant by retting process. Retting and extraction processes have a profound effect on the quality of fiber and on the cost of fiber production. In the conventional retting, jute plant is immersed in clear slow flowing water for 14–28 days to degrade the pectic materials, hemicellulose, and lignin. Conventional retting process is not environmental friendly and requires large amount of water. Therefore, Bangladesh Government has introduced ribbon retting method in different areas of the country to ease peeling of jute fiber. In this paper, effect of ribbon retting on the chemical properties of jute fiber and jute stick was carried out. Pentosan, extractive and ash content in ribbon retted jute fiber and jute stick were higher and lignin and α-cellulose content were lower than the conventional retted jute fiber and jute stick. These differences were pronounced for jute stick. Effect of ribbon retting on kraft pulping was also studied. Pulp yield of conventional retted jute fiber and jute stick was higher at any kappa number. The variation of papermaking properties of the produced pulp on retting process was insignificant. The bleachability of jute fiber pulp was better than that of jute stick pulp. Conventional retted fibers showed slightly better bleachability. Jute fiber pulp consumed 15 kg ClO_2/MT of pulp to produce brightness of 81–86%, while jute stick consumed 30 kg ClO_2/MT of pulp to produce brightness 85%.

1. Introduction

Jute is an annual renewable fiber crops grown mainly in Bangladesh, India and other Asian countries. It is one of the largest sources of lignocellulosic bast fiber which is extracted from plants by a natural microbial process known as retting. Retting has been used for a long time in case of extraction of fibers from jute. In general, the practice of retting jute plants in the jute growing regions is to immerse the jute bundles in clear slow flowing water in canals, rivulet, tanks, ponds or ditches. The minimum ratio of plant material to water in stagnant water should be 1:20. Retting and extraction processes have a profound effect on the quality of fibre produced, and on the cost of fiber production. It affects the efficiency of manufacturing, the quality of the end products and their competitiveness in the market. Retting is the main challenge for extracting bast fiber from the plants. The conventional retting requires 14–28 days to degrade the pectic materials, hemicellulose, and lignin (Paridah et al., 2011). But acute shortage of water for retting and the environmental pollution created from conventional system of retting has demanded for new method of retting. Due to heavy competition in fiber markets, jute producers are interested to improve retting and extraction processes, decrease their reliance on water. The process should be less labour-intensive, lower costs and, above all, enhance the quality of the fiber produced.

To overcome the shortfall of conventional retting, different retting methods have been studied. Ramaswamy et al. (1994) retted kenaf stalks by bacterial and chemical processes. Fiber quality from bacterial retting was superior, but combination of bacterial and chemical method showed advantageous. Banik et al. (2007) showed that inoculation of a specific mixed bacterial culture in combination with 0.5% urea as N-supplement caused faster ribbon retting of jute and kenaf. The mixed bacterial culture in combination with urea produced stronger, finer and brighter coloured jute and kenaf fiber compare to uninoculated control. Jalaluddin (1970) retted jute with *Bacillus polymyxa* at a temperature of 40° in the shortest period of retting, three days. Retting in a tank was appreciably hastened by using the same water for successive batches of jute. Das et al. (2015)

* Corresponding author.
E-mail address: sarwar2065@yahoo.co.uk (M.S. Jahan).
[1] Department of Applied Chemistry and Chemical Engineering, Dhaka University, Dhaka, Bangladesh.

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studied on whole plant retting of jute and mesta with microbial consortium from jute retting water containing polygalacturonase, pectinlyase and xylanase activity. Under controlled conditions this microbial consortium reduced the retting duration by 7 days for jute with improved fiber quality. Pectinolytic enzymes were found to ret green jute ribbons within 48 h, producing fairly good quality jute fibres (Majumdar et al., 1991).

The new method of retting launched has been recognized as ribbon retting. In ribbon retting barks are removed from jute plants in the form of ribbon. The ribbons are coiled and then allowed for retting in water with or without using a microbial inoculum. Ribbon retting requires lesser volume of water, lesser time, creates lesser environmental pollution, and produces improved quality fibre (Banik et al., 2003, 2007). Addition of efficient pectinolytic microbial inoculum may further faster or improve the ribbon retting process. Therefore, ribbon retting process invented to peel jute fiber and rot it in small water. In 2011 Bangladesh Government has introduced ribbon retting method in different areas of the country to ease peeling of jute fibre.

Due to the different microbial action in the conventional and ribbon retting, the chemical properties are obviously different, which may affect pulping of jute fiber and stick. No report has been found on chemical properties of ribbon retted jute fiber and stick.

In this paper, a study has been carried out on ribbon retted (RR) and conventional retted (CR) jute fibre and stick regarding the difference of chemical constituent and its influence on kraft pulping.

2. Material and methods

2.1. Materials

Ribbon retted and conventional retted jute fiber and jute stick were collected from the Bangladesh Jute Research Institute, Dhaka. These were chopped into 2–3 cm in length, and ground (40/60 mesh) in a Wiley mill for chemical analysis.

2.2. Chemical analysis

The extractives (T204 om 88), Klason lignin (T211 om 83), and pentosan (T223 cm-84) were determined in accordance with Tappi Test Methods. Holocellulose was determined by treating extractive free wood meal with $NaClO_2$ solution. The pH of the solution was maintained at 4 by adding CH_3COOH–CH_3COONa buffer. All experiments were carried out thrice and average reading was taken.

2.3. Pulping

Kraft pulping was done in a 5 l capacity thermostatically controlled electrically heated rotary digester. The active alkali was varied from 14 to 18% as Na_2O on oven dried (o.d.) sample in the liquor ratio of 1:5. The cooking time was 60 and 120 min at the maximum temperature (170 °C). At the end of pulping, pressure was released to atmospheric pressure; pulp was taken out from the digester, disintegrated and washed by continuous flow of water. Pulp yield was determined as dry matter obtained on the basis of o.d. raw material. Kappa number was determined in accordance with T 236 cm-85.

All pulps were beaten in a PFI mill to 0, 1000 and 2000 revolution for jute stick pulp and 0, 1500 and 3000 revolution for jute fiber pulp and handsheets of about 60 g/m^2 were made in a Rapid Kothen Sheet Making Machine according to German Standard Methods DIN 106. The physical properties of handsheets were determined following Tappi Standard Test Methods.

2.4. Bleaching

The pulp obtained from RR and CR jute fiber and jute stick were bleached by $D_0E_pD_1$ bleaching sequences. The ClO_2 charge in the D_0 stage was 1% for jute fiber pulp and 2% for jute stick pulp. The temperature was 70 °C in D_0 stage for 60 min. The pH was adjusted to 2.5 by adding dilute H_2SO_4. In the alkaline extraction stage, temperature was 70 °C for 60 min and NaOH and H_2O_2 charges were 2% and 0.5%, respectively. In the final D_1 stage, pH was adjusted to 4 by adding dilute NaOH. The strength properties of bleached pulps were determined according to Tappi Test Methods T 220 sp-96.

2.5. Evaluation of papermaking properties

RR and CR jute fiber and jute stick pulpsheets were tested for tensile (T 494 om-96), burst (T 403 om-97), tear strength (T 414 om-98) and brightness (T525 om 92) according to TAPPI Standard Test Methods.

3. Results and discussion

3.1. Chemical characteristics

It is evident from Table 1 that the cold water, hot water solubilities and extractive content (acetone) in conventional retted jute fiber and stick were lower than those of corresponding ribbon retted jute fiber and jute stick. The cold water treatment removes a part of extraneous components like tannins, gums, sugars, inorganic matter and colored compounds present in lignocellulosic biomass whereas hot water treatment removes in starches addition. The higher water solubility adversely affects the pulp yield. High extractive contents in raw material are undesirable for pulping, bleaching and papermaking. Acetone extractive content was 1.7 vs 0.8 for jute stick and 0.33 vs 0.25 for jute fiber, respectively. One percent alkali solubilities of jute fiber and jute stick in both retting processes were almost similar (31% for jute stick and 21% for jute fiber). Banik et al. (2003) showed that ribbon retting removed pectin completely while fat and wax removed partially from bark. The higher NaOH solubility of stick was possibility due to the presence of low molar mass of carbohydrates and other alkali soluble materials.

A big difference in pentosan content of jute stick was observed between conventional and ribbon retted jute stick. Pentosan content in ribbon retted jute stick was 21.0% while it was 15.8% in conventional retted jute stick. In the conventional retting process jute stick is submerged in water, which is cause less pentosan in conventional retted jute stick. But the pentosan content in ribbon retted jute fiber was only 0.6% higher than that of conventional retted jute fiber. This was due to longer time of retting in the conventional retting process removed more pentosan. Banik et al. (2003) observed a part of hemicelluloses removal from jute fibre in the ribbon retting process, while lignin was unaffected. In the pulping process, lignin is undesirable polymer that needs to be removed with the expense of energy and chemicals. Raw materials with lower lignin content are suitable for delignification. In this study, it was observed that the lignin content in ribbon retted jute stick was slightly lower than the conventional retted jute stick, while lignin content in ribbon retted jute fiber was slightly higher than the conventional retted jute fiber. Klason lignin in conventional and ribbon retted jute fiber was 12.7% and 13.8%, while that of 25.1% and 23.9% for jute stick, respectively. This can be explained by higher removal of hemicelluloses, extractives and minerals in the conventional retting process of jute bark.

The mineral components of lignocellulosic biomass represented as ash content. Higher ash content is undesirable during refining