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Accelerated Retting of Jute for Economic Fibre Yield

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Abstract

Jute fibres are separated from non-fibrous tissues and woody part of the stem by dissolution and decomposition of pectins and gums by a process called retting. Retting employs the joint action of microbes and moisture to dissolve the cellular tissues and pectin surrounding the bast fibre bundle. The huge amount of clear water requirement and environmental hazards caused by chemicals and microbes presents the major disadvantage of retting. Moreover retting is time consuming and costly.

An experiment conducted at National Institute of Research on Jute and Allied Fibre Technology (NIRJAFT), Kolkata, showed that chemical retting of jute was completed within one week using a cheap chemical accelerator without causing any major environmental pollution.

Keywords: Jute, pectin, retting, chemical accelerator, textile

Jute is one of the cheapest textile fibre of immense economic importance. It is one of the most affordable natural fibres and comes next to cotton in amount produced. Jute plant may be categorized into two types, namely, white jute or *Corchorus capsularis* and tossa jute or *Corchorus olitorius*. Jute yields phloem fibre which is mainly composed of cellulose (major component of plant fibre) and lignin (major component of wood fibre). The bark of the plant contains this lingo-cellulosic fibre. Thus jute fibres and jute sticks are a typical source of ligno-celluloses. The main constituent of the fibre is á-cellulose, hemicelluloses including uronic acid derivatives and lignin (Ray *et al.* 2014). Bioconversion of cellulosic materials into many useful products like cellulase, alcohols, organic acids etc. have considerable importance.

Although in some of the lignocellulosic fibre crops like ramie and banana mechanical decortication is the major steps to separate the fibres from the plants (Nayak *et al.* 2012; Ray *et al.* 2014a; Ray *et al.* 2014b; Ray *et al.* 2012), jute is preferably separated out through retting process. The fibres are separated from the woody core of the stem by steeping the bundles of the harvested and the defoliated plants in water of various sources (Ray *et al.* 2015; Saha and Banerjee 1955). The fibre cells are cemented together by pectin and gummy substances (Deb 1954; Mian *et al.* 1996). The process of separating and extracting fibres from non-fibrous tissues and woody part of the stem by dissolution and decomposition of pectins, gums and other mucilaginous substances is called retting (Gupta *et al.* 1976; Majumdar and Day 1977). The process employs the joint action of microbes and moisture to dissolve the cellular tissues and pectin surrounding the bast fibre bundle facilitating fibre separation from the stem.

There are different types of retting practiced in India. Water retting produces more uniform and high quality fibre, but it requires both labour and capital. The most widely practiced method of retting is water retting. Bundles of stalks are submerged in water. The water

penetrates to the central stalk portion, swells the inner cells and bursts the outermost layer, thus increasing absorption of both moisture and decay-producing bacteria. Retting time must be carefully judged; under-retting makes separation difficult and over-retting weakens the fibre. The plants were harvested at 120 days maturity and defoliated. The green stems were immersed in retting tank and covered with polythene sheets. After three weeks the retting was completed. It is a time consuming process and needs a huge quantity of water for retting. If the retting is not conducted properly the fibres of the basal parts of plant remain hard. The hard basal parts of the fibre are called cuttings (Saha and Banerjee 1955). The less is the percentage of cuttings, more is the fibre quality.

In double retting, a gentle process for producing excellent fibre, the stalks is removed from the water before retting is completed, dried for several months and then retted again.

Natural water retting employs stagnant or slow-moving waters, such as ponds, bogs, slow streams and rivers. The stalk bundles are weighted down, usually with stones or wood, for about 8 to 14 days, depending upon water temperature and mineral content.

Tank retting employs vats usually made of concrete, requires about four to six days for completion of retting and is feasible in any season. In the first six to eight hours, called the leaching period, much of the dirt and colouring matter is removed by the water, which is usually changed to assure clean fibre. Waste retting water, is rich in chemicals and can be used as liquid fertilizer. This waste water requires treatment to reduce harmful toxic elements before its release to natural environment.

Dew retting is a common method in areas with limited water resources. It is most effective in climates with heavy night time dews and warm daytime temperatures. The harvested plant stalks are spread evenly in grassy fields, where the combined action of bacteria, sun, air and dew dissolve much of the stem material surrounding the fibre bundles. Within two to three weeks, depending upon climatic conditions, the fibre can be separated. Dew-retted fibre is generally darker in colour and of poorer quality than water-retted fibre.

Retting can be also carried out by using a large variety of micro-organisms. This type of retting often requires a minimum amount of water and may be referred as dry retting. Different types of fungi, aerobic and anaerobic bacteria are involved in retting. Micro-organisms attack cambium and secondary phloem as they have no effect on hard wood. The microbes secrete specific enzymes to decompose parenchymatous tissues. Pectisinase, pectase and pectinase enzymes are mainly used to hydrolyze the pectic substances which cement the vascular tissues of jute plant. The enzyme pectisinase converts pectic substances into soluble pectin which is then activated by pectase to produce pectic acid (Bhuiyan *et al.* 1979). At the initial stage of retting, due to high pH value, the growth of bacteria is vigorous and the enzymatic reaction increases. As the reaction proceeds, slowly the bacterial growth decreases due to decrease in pH value (Haque *et al.* 2001).

Ahmad *et al.* (2008) isolated aerobic and anaerobic bacteria from retted jute stems. They have been found to comprising three genera, *Bacillus, Micrococcus,* and *Pseudomonas* and thirteen species. Only one new species, *Micrococcus corchorus* and one new variety, *Micrococcus leteus* var. *liquefaciens*, are reported. Among the aerobes and facultative anaerobes, *Bacillus subtilis* has been found to be most common and *B.* macerans, *B. polymyxa*, *Micrococcus corchorus* and *Pseudomonas aeruginosa* the most active retting agents.

If the retting is continued beyond the optimum period of time, micro organisms begin to degrade the cellulose of the fibre. Such a condition is known as over retting.

Materials and Methods

Extraction of jute ribbon

Among the various factors that influence the fibre quality starting from seedling to fibre extraction, the retting and extraction have been identified to be the most significant in yielding quality fibre. An alternative method of extracting jute fibre has been evolved such as ribboning of green stems by mechanical devices and retting the ribbons in a small volume of water instead of stem retting. ICAR-NIRJAFT has developed a post-harvest technology for accelerated retting of jute which involves ribboning of green jute plant by a manual ribboner or a power ribboner.

In ribbon retting the volume of biomass to be retted comes down to about 40% only. The retting time is also reduced. The release of organic matter into water is less than one third that of stem retting. Such factors enable the ribbon retting to be conducted in almost one-fourth the water used in stem retting and more number of retting can be done in the same water.

Accelerated retting of jute

Accelerated retting of jute ribbon is carried out with an aqueous solution of the chemical accelerator

formulated by ICAR-NIRJAFT, Kolkata, in minimum quantity of water just sufficient for wetting the ribbons which produces good quality of fibre in higher yield. A standard chemical recipe of the chemical retting agent with the standardized parameters is given in Table 1. From 100 kg of green plant about 40 kg of ribbon is extracted by power ribboner. Since water requirement of this process is 100 litres per quintal, for 40 kg of ribbon, only 40 litres of iron-free clear water was sufficient. Retting water was inoculated with previous retting water to get better result. 280 g of chemical recipe was mixed thoroughly with 40 litres of water and jute ribbons were completely immersed into the water using bricks and blocks made up of bio-composites. After 5 days, the ribbons were regularly checked by hand and eye method to note down the completion of retting.

Table 1. Chemical recipe for retting of jute

Ribbon extracted from 100 kg of green plant	40 kg
Amount of water required for one quintal of green plant	100 litre
Chemical formulation required per litre of water	7 gram

Results and Discussion

The retting was found to be completed within 7-10 days depending upon the nature of water, type of plant, temperature and inoculum used. In the present study, the retting was completed by the 9th day from the date of immersion of ribbons. The initial pH of the water after adding the chemical recipe was as high as 10.5 to 11.5 (Table 2). This high alkaline pH reduced gradually and became 3.5 to 4.5 at the end of the retting indicating the presence of organic acids released during the process. The temperature of the retting water during these 9 days varied from 25-35^{O}C.

Traditional retting of jute takes 15 to 20 days and requires large quantity of water which should be preferably slow-flowing water. Ponds in villages are not allowed for jute retting in general as the water turns dark and foul-smelling making it unfit for domestic use and pisciculture, breeds mosquitoes and creates environmental problem. Erratic rainfall also creates water scarcity for retting of jute. In the absence of adequate retting facilities, jute is mostly retted by immersion in stagnant and insufficient water in ditches repeatedly in batches by which the colour and quality of fibre degrades to grade 4, 5 or even 6 and the farmers are deprived of their earning of hard labour.

Moreover, farmers may suffer from health related problems due to working in waist-deep dirty and stagnant water for long hours. The young generation of farmers is losing interest in jute cultivation for the occupational hazard and un-remunerative price of their hard labour.

The new jute retting technology will benefit the farmers in various ways. Jute is harvested in 100-120 days in traditional cultivation. In the new retting process, 90-100 days old jute can be harvested and ribboned in the new ribboner machine taking 10-12 green plants at a time. Jute ribbons are made into small bundles and retted with the aqueous chemical solution of 0.5 – 0.7 per cent concentration in a kuchha retting tank made with polythene sheet or in a cemented pucca retting tank. Retting is completed within 8 days (Table 2) and golden lustrous high quality fibre between grade 2 and 3 is obtained on washing of retted ribbon in water. At least 1% higher yield of fibre is obtained in ICAR-NIRJAFT retting technology due to minimum loss of fibre during ribboning and washing of retted ribbons. The plant to water ratio in the ICAR-NIRJAFT retting technology is greatly reduced to 1:1 only while traditional retting practice requires 1:20-25 ratio of plant and water. Moreover, whole jute stick of better strength and quality is obtained without breaking through ribboning of green plants compared to the stick obtained after 2 to 3 weeks immersion in water in traditional retting. Jute stick is an important by-product to farmers for fuel, fencing, betel leaf cultivation, etc. The technology has been successfully demonstrated in the fields in blocks of different districts of West Bengal in which the farmers, State agriculture officers and NGOs participated.

Table 2. Physical and physico-chemical parameters

Initial pH of retting water	10.5-11.5
pH at which final retting occurs	3.5-4.5
Average water temperature	25-35°C
Average atmospheric relative humidity (RH)	85-90 %
Completion period retting	7-10 days

The fibre and yarn quality of the chemically retted jute was tested in the laboratory and found that the grade of jute improved from TD – 5 to TD – 4. The fibre strength varied from 22.5 to 26.3 g/tex which was much better than traditionally retted jute. The yarn parameters of the retted fibre also improved considerably (Table 3). Average tenacity and fibre bundle tenacity suggested that the retting by chemical means was undoubtedly the best. Due to less immersion time in water the fibres were not over-retted, thus improving the over-all fibre quality.

Table 3. Yarn parameter values of chemically retted jute fibre

Fibre characteristics	
Fibre strength	22.5 - 26.3 g/tex
Fibre fineness	2.6 - 3.2 tex
Average root content	5%
Average fibre grade	TD – 4
Yarn properties of chemically retted jute (8 lb)	
Average tenacity	23.24 cN/tex
Work of rupture	2.7 mN/tex M
True density	1.48 g/cm^3
Fibre bundle tenacity	20.3-32.6 g/tex

Biochemical events occurring during retting of jute

Retting means partial rotting of any living materials. Retting can be defined as a process by which the fibre bundles get separated from non-fibrous tissues and woody parts of stem. Production of good quality jute is primarily dependent on retting. The quality, quantity, nature and temperature of water during retting, presence of micro-organisms etc. are the controlling factors of jute retting. Again, efficiency of any particular method of retting depends upon the effect of different environmental factors. ICAR-NIRJAFT has worked exhaustively on these aspects of retting phenomena and recommended several measures to improve the fibre quality at farmer's level.

Through our study, it was found that jute plants, irrespective of species, jute harvested at 120 days produce fibres of better strength than 140 fays old plants. It was also observed that microbial action in retting water is maximum at a depth of 15 cm from the surface of water and retting is quicker and better at this depth. Some microbial action is evidenced even up to depth of 35 cm, but below this practically no effect has been observed.

From our study, it has been observed that the bacterial count in retting water increased up to seventh day when it reached maximum and then there was sharp fall in the number. As the actual process of separation of fibres takes after this period, it can be inferred that either that either facultative or strict anaerobic microbes are the causative agents carrying out actual retting.

During retting process, a series of biochemical reaction takes place as a result of which chemical composition, pH, Eh and BOD of retting water change continuously. It was observed that release of total sugars increased gradually during retting process up to thirteenth day and beyond this period the increase was significant indicating a condition of over retting, when decomposition of cellulosic components takes place. Galactouronic acid, the main degraded product of pectin, reaches the peak on the thirteenth day, when retting is completed. Pectin is the major binding material between the jute fibres. The maximum galactouronic acid release may be regarded as an indication of completion of retting and over retting starts beyond this period, when decomposition of cellulosic fibre occurs as indicated by excess release of soluble sugars in the retting liquor.

It was also observed that BOD of retting water steadily increased with progress of retting and reached the peak between twelve and fifteen days. The pH of retting water during this period became acidic and then gradually reached neutral values at the completion stage. The redox potential of the water similarly decreased during progress of retting and remained constant during progress of retting and remained constant during twelfth and fifteenth day. The results clearly indicate that the dissolved oxygen was quickly exhausted due to microbial activity and biochemical oxygen demand (BOD) in water increased due to increase of dissolved and particulate organic matter in water. Drop in pH with progress of retting is due to release of acidic components especially galactouronic acid (Table 2). Drop in pH values clearly indicates that anaerobic environment was established in water during the progress of retting.

Since the retting process is normally slow, several workers have attempted to hasten the retting processes and improve the quality of fibres by various methods. These methods include addition of chemicals, pure culture of bacteria, pectinolytic enzymes derived from certain bacteria and fungi. ICAR-NIRJAFT has developed a farmer friendly technology for faster retting of jute through extraction of jute ribbon followed by chemical retting.

Conclusion

The improved process has several advantages over the conventional retting process.

(a) ***Accelerated retting for fibre extraction:*** The ribbon retting by ICAR-NIRJAFT technology takes 7-8 days (Table 2) using chemical formulation for completion of retting while conventional retting of plants takes 15-20 days.

(b) ***Less water requirement:*** The conventional retting of plants requires 20 to 25 times of water while in chemical retting process the plant: water ratio is 1:1 only.

(a) ***Better fibre quality:*** ICAR-NIRJAFT retting process yields fibre of better qualities in colour, strength, fineness and graded between 3 and 4 grades (Table 3) as per BIS standard while conventional retting yields mostly fibre in the grades 4, 5 and even 6 due to improper retting conditions.

(b) ***Higher fibre yield:*** Conventional retting yields about 6% fibre on green plant weight while chemical retting technology records at least one per cent higher yield due to efficient ribboning and less biomass handling during extraction of fibre from retted ribbons.

(c) ***Less Biomass handling:*** While conventional retting requires steeping of the whole plant in water, only 40% of biomass in the form of jute ribbons is handled in chemical retting process as jute stick constituting about 60% of biomass is extracted by ribboning before the retting operation.

(d) ***Eco-friendliness:*** The improved ribbon retting is environment-friendly as it does not pollute water bodies emanating foul smell and relieves farmers of the occupational hazard and health risk for working in polluted water during fibre extraction. The chemicals used are not hazardous.

(e) ***Cost-benefit:*** The improved ribbon retting yields fibre of better grade in higher yield which would fetch higher market price to the farmers of their produce.

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