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Improved retting methods of jute to enhance fibre quality and retting waste management

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Abstract
The quality jute fibre production entirely depends upon the process of retting not only on the production of jute. Retting is a rotting process generally preferred to separate the fibre from woody stem without damaging the fibre cellulose. Retting microbes consumes pectin and hemicellulose mainly that are non fibrous cementing materials. Over retting causes degradation of fibre cellulose while under retting does not allow removal of gummy materials completely that are pectic substances. Over retting as well as under retting causes production of low grade jute fibre. Moreover, jute fibre retting and extraction are also labour-intensive, depending upon productivity and the level of technology used. Production of quality jute fibre depends on the process of retting in presence of good quality water. Microbial retting and the extraction of the fibre from the woody core are important primary operations in the processing of jute crops for fibre production. This involves the immersion of bundles of plants in open water, lakes, rivers, ditches, canals and ponds and the controlled decomposition of the non-fibrous materials connecting the fibres to the bark of the plants by using aquatic microbes. Ribbon retting also reduces time of normal retting by 4-5 days, saves water, space and the cost of retting process up to 50% over the traditional method. These improved methods of jute retting able to produce higher quality of jute fibre.

Keywords: quality fibre, microbial retting, ribbon retting

Introduction
Jute (*Corchorus capsularis* and *C. olitorius*) is less expensive and is second only to cotton in amount of production as well as most versatile of textile fibres. The fibres are biodegradable, renewable, and helps in providing employment in rural areas. Jute fibres are used in manufacture of colourful carpets, carpet backing, cordage, decorations, apparel fabrics, blankets, geo- and agro-textiles, non-woven materials, industrial fabrics, thermal insulations and numerous utility items in a range of traditional and innovative uses. As the demand for natural comfort fibres increases, the demand for jute and other natural fibres that can be blended with cotton will increase (Basu *et al.* 2005) [6]. Moreover, leaf and crop trash remains in the field can be recycled for using as organic materials, thereby reducing demand for supplementary chemical fertilizers for subsequent crops. Retting of jute is a type of fermentation process in which the cortical and phloem tissues of the bark of the plants containing free strands are decomposed in order to separate fibre from non-fibrous woody stem (Haque *et al.* 2001) [15]. Slow moving clean water used for retting produces best quality fibre, but such conditions are rarely prevailed in the jute growing areas of India (Chapke *et al.* 2011) [8]. Fibre retting and extraction are also labour-intensive but provide employment to farmers, their families and to landless labourers in the community. However, in this process the level of drudgery is high, and people working for long hours immersed in polluted water are prone to health risks. Retting microbes utilize free sugars, pectins, hemicellulose and proteins of the plants as essential nutrients for their development and multiplication under the favourable condition (Munshi *et al.* 2008) [20]. Fibre quality is dependent on retting in different natural conditions and duration of retting (Ahmed *et al.* 2008) [2]. The jute stem vascular system is cemented by three types of pectins or pectic substances which are hydrolyzed by the enzymes namely pectisinase, pectase and pectinase and finally broken down to glutamic acid. The retting water becomes acidic at later stage of retting due to the presence of organic acids (acetic, lactic, butyric, ketoglutaris), acetone, ethyl alcohol, butyl alcohol and various gases (Debsharma, 1976) [9], resulting in decrease in the growth of retting bacteria in comparison to higher growth observed at initial and middle stage of retting.

Conventional Retting

The traditional whole plant retting method of jute is practiced worldwide since the start of jute cultivation. The traditional and most common method of retting is known as stem retting, in which the complete plant stem is immersed in water in bundles of multiple layers called as rets. After the harvesting of jute, the plants are kept in the field for defoliation/leaf shedding for a duration of 3 to 4 days. During the period of leaf shedding, the living cells of jute plants start to die and this is the beginning of the retting process. The defoliated jute bundles are then transported to the nearest retting facilities, immersed in clean or stagnant water according to the availability in natural retting tank, road-side ditches, sometimes in river with locally available materials. Most of the farmers use mud/soil and banana logs for immersion of jute bundles in water. In this method, the retting of jute is completed in 18-21 days. The fibre is then extracted manually by "beat-break-jerk" or single plant extraction method which varies from place to place. After the process of extraction, fibre is sun dried, tied and transported to market for sale. The quality of the fibre produced can vary. Use of mud/soil and banana plants for retting purpose helped in the production of ferrous tannin which imparts black colour to the fibre.

Table 1: Comparative Assessment of Improved and Conventional Retting of Jute on Retting Duration, Fibre Recovery and Quality (Das *et al.* 2017) [11].

Quality parameters	1st retting		2nd retting		3rd retting		C.D. (P = 0.05)
	Improved retting	Conventional retting	Improved retting	Conventional retting	Improved retting	Conventional retting	
Retting duration (day)	14	21	13	20	13	19	2.09
Fibre recovery (q/ ha)	27.2	24.8	28.5	25.5	29.0	25.9	1.68
Fibre strength (g/tex)	26.4	23.0	25.7	21.7	25.3	20.7	1.44
Fibre fineness (tex)	2.76	3.10	2.82	3.20	2.93	3.25	0.20
Fibre colour	Golden	Greyish	Golden yellowish	Blackish	Golden yellowish	Blackish	-
Root content (%)	03	15	04	17	04	17	-
Lustre	Bright and shining	Dull	Bright and shining	Dull	Bright and shining	Dull	-

Improved Retting Technologies with Microbial Formulation

Availability of good quality retting water is the main hindrance for carrying out retting of jute with quality fibre production. Retting of 50 to 60 tonnes of green biomass/ha needs a huge volume of fresh water. By considering this, several new retting methods were developed which required very less water compared to traditional method of retting. These new improved methods of retting are in conjunction with microbial formulation. The fibre strength of jute ranged between 25.3 and 26.4 g tex^{-1} and 3–4% of root content in resultant fibre in improved retting as compared to 20.7–23.0 g tex^{-1} and 18–20% respectively in conventional retting (Table 1). Higher root content in jute fibre indicates poor quality fibre.

Retting of Green Ribbon with Microbial Retting Formulation

The green ribbons can be extracted by either of the above mentioned extractors are then kept in polyethylene lined or concrete retting tank for retting. The ratio between green ribbon and water is kept as 1: 5. The green ribbons: water ratio should be maintained strictly for application of formulation and proper retting. Microbial formulation at the rate of 1 kg per 2q of ribbons with a cfu of 10^{10} to 10^{12} per gram of formulation is added in the retting water of the tank. After completion of the retting, ribbons are washed in clean water for obtaining good quality fibre. The same retting water can be used for retting again, by removing half of the water and filling it with fresh water (Majumdar *et al.* 2013) [19]. No fresh application of formulation is needed for further retting in the same retting tank. Mechano-microbial retting technique was developed with an objective of carrying out efficient retting in very less amount of water by reducing the volume of green jute plants by extracting green ribbons immediately after harvest and retting with the use of microbial consortium/formulation (Saha *et al.* 2009; Majumdar *et al.* 2009) [22, 18]. Availability of good quality retting water during retting period is a great concern; hence improved method of mechano-microbial retting is the most appropriate one under severe water scarcity situation. Top and bottom parts of the jute plant, if retted separately followed by malleting 40 cm of the basal part improved the fibre quality and showed more or less uniform retting. *Sporotrichum* sp., *Schizophylum communae* and *Trichoderma* sp. retted green ribbons of jute (var. CVL-1) in 7, 9 and 11 days, respectively, while the others did not show any retting efficiency (Table 2).

Table 2: Comparative studies of retting properties of different released varieties of jute (Haque *et al.* 2001) [15].

Variety	Retting time (Days)	Final pH	Fibre colour	Fibre grade	Cuttings (%)	Fibre yield (kg/100 kg bark wt.)
C-718	12	6.80	White	A	2	10.50
OF-390	11	6.59	Golden	B	4	9.00
C-2035	14	7.00	Brown	C	15	9.00
OM-1	11	6.90	Golden	B	6	10.50
C-2005	14	6.77	Shamla	C	20	10.50
C-2143	13	6.81	Brown	C	10	10.50
Control-1 (CVL-1)	16	7.01	Light brown	C	25	11.05
Control-2 (O-9897)	17	7.00	Light golden	C	30	10.75
*Level of significance	0.01	0.01	**NS	*		

*Mean followed by a common letter are not significantly different at the 5% level of DMRT. **NS=Non significant.

Merits of Mechano-microbial Retting

- This method requires less volume of water, so it is best suited for water scarce areas.
- Retting is completed within 7-9 days in comparison to 18-21 days required under conventional whole plant retting.
- Total fibre production is more than traditional whole plant retting, where a substantial portion of fibre is lost during retting and washing.
- The fibre is of golden yellowish colour with very good lusture.
- The fibre quality is improve by 2 grades (from TD6 to TD4) in this method in comparison to conventional method which often produces dark coloured fibre.
- The net income is increased by Rs. 5000 - 6000/ha than conventional method, because of more productivity and better quality.

***In-Situ* Retting of Jute with Microbial Formulation**

In-situ retting of jute is introduced to eliminate the carrying cost of harvested jute plants to the retting site by carrying out retting in the jute field itself with reduced amount of water than traditional retting. Under water crisis situation, in the absence of normal rainfall during retting season, this method of retting was prescribed by using underground or lifted water in the polyethylene lined retting tank with microbial formulation for retting in less time, so that the farmers are not affected by the drought like situation during retting season of jute. This improved method of retting involves construction of a circular micro-pond of 6.5 m floor diameter, 7.5 m top diameter, and 1 m depth having 1 m wide earthen embankment in the lowest corner of the jute field, so that farmers need not carry their harvested jute to a distant retting site for retting (Ghoral *et al.* 2009) [13]. This retting tank is lined with polyethylene sheet, which is sufficient to ret jute harvested from one bigha (0.13 ha) of land with the help of CRIJAF microbial retting formulation in a 1: 1 ratio of jute plants: water within 12- 15 days with 2 to 3 grade improvement in fibre quality.

Merits of *In-situ* Retting

- Retting is completed within 12 to 15 days in comparison to 18 to 21 days under conventional retting.
- Transport cost of Rs. 3500 to 4000/ha required under traditional method for carrying harvested jute bundles to the retting spot can be eliminated by this method.
- The quality of fibre can be enhanced by 2 to 3 grade.
- The famer can be benefitted by Rs. 5000 to 6000/ha over traditional method.
- The pond embankment can be utilized for plantation of high value vegetable crops (early cauliflower, cabbage, brinjal, tomato, capsicum, etc.), which will compensate the cost of polyethylene.
- Retting wastes works as green manure in the field, and the impounded water gives a measure of control over nematode infestation.
- The pond after completion of retting process can be used for fish cum paddy culture.

Chemical Retting

In chemical retting, the cementing material can be removed by dissolution with certain chemicals. The fibre obtained by chemical method of retting seems to be a little coarser, rough in the feel and stiff. The gravimetric fineness values do not differ very much from that of microbially retted fibre. The fibre strands after drying needs to be softened by rubbing with hand to open up the fibre and to remove the stiffness of the strand. A cationic softener may be used to the extent of 0.2% on the weight of the fibre. Ammonium oxalate and sodium sulphate was found to be suitable, as in chemical retting the fibers are extracted under controlled condition and the fibre properties are not affected by the treatment, the procedure may be adopted as a standard method of fibre extraction from jute (also mesta) ribbons (Gupta *et al.* 1976) [14]. The process is, however, costly and is net practicable in the cultivator's field. The method has no adverse effect on the fibre properties.

Different Bacterial and Fungal Cultures

Many bacterial cultures are efficient retting agents. The JTRL India tested large numbers of water bodies used for retting and identified a mixed bacterial culture capable of retting in 2-3 days and kept samples of the culture for further experiments. Main aerobic retting bacteria belong to genus *Bacillus viz*., *B. subtilis*, *B. polymyxa*, *B. mesentericus*, *B.pumilus*, *B. cereus*, *B. megaterium and B. macerans*, initiate retting (Nath *et al.* 2017, Das *et al.* 2015) [21, 9] along with large numbers of gram-negative genera such as *Erwinia* and *Pseudomonas* (Ahmed *et al.* 2008, Islam *et al.* 2013) [2, 16]. *Bacterium felsenium* significantly reduces the retting period and enhances the fibre quality (Ali *et al.* 1972) [4].

The Bangladesh Jute Research Institute (BJRI) screened fungi of different origins and found that the saprophytic fungus (*Sporo tricchum*) was capable of retting dry ribbons of jute satisfactorily, under laboratory conditions. Post-retting treatments with the use of fungal cultures were also tested to reduce the effect of cuttings on the fibres by eliminating the hard and barky bottom portion without negatively affecting other fibre qualities. *Aspergillus* sp. was found to be advantageous in enhancing the quality of fibres produced by one or two grades. By a pectinolytic fungal culture, *Penicillium corylophilum* Dierckx. an inferior quality barky jute may be upgraded by 1-3 grades (Bhattacharyya and Basu, 1981) [7]. Basak *et al.* (1987) [5] indicated that the fungus *P corflophyium* could soften the barky jute without affecting the cell walls of the fibers.

Bleaching Treatments

The dark colouring of fibres due to soil contamination or poor retting practices reduces the quality of the fibres produced. Mainly low-cost bleaching treatments with the use of materials freely available in jute-growing areas. These consists bleaching extracts of tamarind leaves and roselle leaves, vinegar and the commercial bleach Clorox. The BJRI Bangladesh found that a 2.5% solution of tamarind leaves was useful. The FCRC Thailand found Clorox to be the most effective, but with decreases the strength of fibre that is from 19 g/tex to 6.4 g/tex. This is unacceptably high; other treatments that reduced the strength of the fibres to less than 25% of the original are recommended.

Fish Culture

Community retting-cum-fish culture is a practical and economical approach. Composite fish stocking can be done after completion of retting season, and after allowing 2-4 weeks for oxygen levels to build up. In large areas of water retting as well as fish culture can take place concomitantly. A harvest of 15 kg fish in 5 months (March to July) of pre-retting water was possible (Ghorai *et al.* 2013) [12].

Crop Treatments

- Where cuttings are a serious issue, the use of pectinolytic post-retting fungal cultures can be used with advantage.
- To remove dark colour staining from jute fibres, low-cost treatments using tamarind fruit pulp or mesta, roselle or tamarind leaf extracts can be prepared and used. Microbial cultures such as retting effluents (2.5-10%) or mixed bacterial culture may be used to speed-up retting, especially if ground water (as opposed to surface water) is being used; ground water normally has low microbial counts.
- The application of low-cost and locally available nitrogenous materials such as urea (at 0.01-0.1% green weight basis) is recommended. Application of *Sesbania* into the ret enhances the rate of retting.
- Defoliation before retting will decrease transport and handling, return organic materials to the soil and decreases the amount of organic load discharged to the retting waters.

Utilization of Jute Wastes

The major potential biodegradable agricultural and agro-industrial cellulosic wastes available in India are rice straw, rice husk, wheat straw, sugar cane bagasse, saw dust, jute sticks, jute mills wastes etc. Jute stick is a ligno-cellulosic material and is one of the most abundant as well as renewable organic resource. It has a great potential as an ecologically beneficial feedstock for producing valuable products including a number of useful chemicals and liquid fuels. Hemicellulose constitutes approximately 39% of agricultural residues by dry weight with aldopentose D-xylose (usually not less than 95%) (Winkelhausen and Kuzmanova 1998) [23] forming the main constituent of this fraction, when it is derived from hardwood or agricultural residues (Kern *et al.* 1998) [17]. Ahmed *et al.* (2001) [1] extracted D-xylose from jute stick by using an easy method. They hydrolyzed jute sticks and rice husks in order to extract D-xylose. When jute sticks were used as substrate, 1 N H_2SO_4 was found to be suitable for D-xylose extraction at boiling temperature after a period of 1 hr. 1 N H_2SO_4 was also found best for D-xylose extraction from rice husks. No cellobiose was detected in hydrolysate. It was found that only 1N H_2SO_4 showed the best result where only D-xylose was extracted without production of any residual by-product during the reaction. It was also observed in the experiment that 1 h hydrolysis with 1N H_2SO_4 seemed to be the optimum for extraction of D-xylose; and prolonged hydrolysis was found to produce a by-product in the hydrolyzed substances besides D-xylose. In case of D-xylose extraction from small pieces of jute stick and jute stick powder, it was found that small pieces of stick are better as compared to the powder (Ahmed *et al.* 2001) [1]. Retting effluent increased the yield in rice and tithe of the soil (Akhter *et al.* 2003) [3].

Conclusion

Scarcity of water or low rainfall retting period compels farmers to ret their jute crop in stagnant water resulting in low quality jute fibre. Under such situation, adoption of modified conventional method of retting, mechano-microbial retting and in-situ retting with microbial formulation will help to produce quality fibre. In areas where the water is scarce, ribbon retting techniques should be introduced and farmers should be made aware. Further commercialization of microbial cultures is recommended, and their use should be promoted. By following these techniques, farmers can ret their jute in lesser time with very less quantity of water along with improvement in fibre quality and get more net income than conventional method of retting.

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