



Critical review on microbial perspective of jute retting

S. SINHA RAY, S. MUKHERJEE, ¹MD. N. ALI AND ²B. MAJUMDAR

IRDM Faculty Centre, RKMVERI, Narendrapur, Kolkata-700 103

¹Department of Agricultural Biotechnology, BCKV, Mahanpur, Nadia, West Bengal, India.

²Division of Crop Production, ICAR-CRIJAF, Barrackpore, Kolkata-700120, India

Received : 11.11.2019 ; Revised : 28.11.2019 ; Accepted : 03.12.2019

DOI : [10.22271/09746315.2019.v15.i3.1248](https://doi.org/10.22271/09746315.2019.v15.i3.1248)

ABSTRACT

Jute is considered as “cash crop” because of its economic importance which chiefly depends on the fiber quality. Amongst several factors, retting is considered to be the most important to obtain high quality fiber. Retting is the result of combined action of aquatic microorganisms and water on jute stem. During this process, enzymatic activities of aquatic microorganisms lead to degradation of “cementing materials” pectin substances between the cells and help to separate the fiber from stem. During retting, microbial status of retting water as well as biological property of water is changed. Literature study reveals the microorganisms having high pectinolytic activity coupled with xylanase activity is essential for effective jute retting while cellulosic activity of microorganisms degrade the fibers itself quality. Microbial jute retting has immense potential under the changed climatic situation due to global warming under water scarcity condition. Keeping view on the interdependent role of both of water and microorganisms, here an attempt has been taken to summarize the retting microorganisms with special reference to their role during retting.

Keywords: Enzyme, jute, microorganisms, retting

Jute, the fiber crop is considered as second cheapest natural fiber in the globe (Ray *et al.*, 2015), holds a significant position in fiber industry by providing nearly 15% of total industrial fibers (Haque *et al.*, 2001). Jute fiber is eco-friendly, recyclable in nature and most suitable for packaging of agricultural goods (Ahamed and Nizam, 2008). Fibers are also traditionally used to prepare mats, wires, carpets, bags etc (Jahan *et al.*, 2011). Beside jute improves the fertility of soil, preserve the ozone layer by absorbing and releasing CO₂ and O₂ respectively. Uses of jute stick for cooking in rural area reduces wood dependency which indirectly reduces deforestation rate (Islam and Ahamed, 2012). In India, jute based and associated industries are income generation source for nearly 4 million families (http://ministryoftextiles.gov.in/pdf/ar03_c11.pdf). Though there are several advantages, but low production of fiber as well as use of substitute (synthetic supplements/plastic) make this industry vulnerable today in terms of its socioeconomic importance (Rahman *et al.*, 2017). So there is need to improve the fiber quality with most updated technologies or diversifying the use of jute fiber to regain its value in international market. Ghosh *et al.* (2014) reported that jute varieties are significantly diversified on their fiber quality in terms of luster, length and rigidity of the fiber. Though fiber quality is influenced by several factors like variety, sowing time, agricultural practices but most important one is the retting (Islam and Rahman, 2013). Retting is carried out by aquatic microorganisms results separation of fiber from the stem. Since retting is major quality determining factor of jute fiber, here an attempt has been taken to review the microbial perspective of jute retting with special reference to its status, role and impact during retting.

Retting: Jute fibers are ligno-cellulosic due to presence of cellulose (mainly), hemicellulose and lignin on it (Duan *et al.*, 2017). Each fiber consists of large number of cells joined together by cementing materials such as pectin and hemicellulose (Deb, 1954; Mian *et al.*, 1996; Ray *et al.*, 2016). During retting, these fibers are isolated from the stem due to combined action of water and aquatic microorganisms (Ali *et al.*, 2015). The effective retting showed superior quality fiber having high market value while improper retting leads to inferior quality of fiber. Retting time varies according to thickness and maturity of stem (Banerjee, 1955). So retting is not only related to fiber extraction but also quality determining factor of fiber i.e. market value of jute fiber (Jahan *et al.*, 2016).

Retting may be either water or dew based retting (Tamburini *et al.*, 2003) but till date most of jute retting based experiment is restricted to water retting due its simplicity. Though there are several problems such as more time consuming, improper retted fiber and more laborious (Chapke and Borkar, 2011) but till now, most of the jute growers are depending on the conventional method of retting over other improved methods of retting (chemical, microbial and mechano-microbial retting).

Conventional Jute Retting: During conventional retting, jute bundles are traditionally immersed in open water reservoir like rivers, canals and ponds with the help of jak materials (Majumdar *et al.*, 2008). Thereafter mud and banana stems are used to put over the jak material for complete immersion of bundles of jute in water. Retting under water stress condition promotes low quality fiber in terms of its color and physiochemical parameters (Banik, 2016). At least 1:20 ratio for plant

to water is suitable for jute retting under stagnant water (Jahan *et al.*, 2016). Besides selection of covering material and deepness of layers of jute bundles are considered to be critical factor to get quality fiber (Kundu, 1956). During retting, the cementing materials i.e. pectins, hemicelluloses and proteins of stem are consumed by the aquatic microorganisms (Banik and Ghosh, 2008). Thereafter, these bundles are taken out from the water to extract the fiber manually from the retted stem (Sarkar and Sengupta, 2015). But this method is time consuming and responsible for water pollution due to biomass deposition within water reservoir.

This problem could be overcome by using the ribbon retting suggested by several authors. In this method, bark is detached from stem prior to transfer into water. Due to this invention, retting microorganism gets more surface area of inner side of the bark with respect to conventional method (Banik *et al.*, 2007). Though ribbon retting is more advantageous over the traditional method in terms of retting duration, water content and environmental pollution (Banik *et al.*, 2003) but more laborious in nature.

Jute retting: Microbial perspective

Status of retting microorganisms during retting:

After immediately transfer of plants into water during conventional retting, water uptake by plants results swelling and rupturing the plant surfaces leads to release of the organic compounds (soluble carbohydrates, proteins and various organic compounds) from the plant body into water (Ahmed and Akhter, 2001). These soluble components are utilized as energy source by retting microorganisms to enhance the microbial population in water reservoir (Ali *et al.*, 1976; Das *et al.*, 2014). At this stage, due to fermentation of the organic compounds, pH and oxygen content of water reservoir is reduced. As a result, anaerobic (especially microaerophilic) microorganisms are found more prevalent during the later stage of retting while aerobic microorganisms are active on initial stage of retting (Islam and Rahman, 2013).

Micro-aerophilic/anaerobic bacteria is entered into the tissues to decompose the cementing materials (mostly pectin) connecting the fiber strands with release of galacturonic acid and sugar in retting water (Basak *et al.*, 1998; Banik and Ghosh, 2008). The greater part of decomposition during retting was performed by anaerobic microorganisms. At this stage, the pH value is again increased because of the formation of buffering organic compound and the retting of the plant is completed (Ali and Alam, 1973; Islam and Rahman, 2013).

Release of organic compounds and its products in stagnant water during retting interfere with the microbial growth and their activity. Hence retting under slow moving water is found better for good quality fiber (Kundu *et al.*, 1952; Ray *et al.*, 2015a).

Biochemical basis of microbial jute retting: Bast fiber is multicellular in nature and the aggregate of cells are joined together by pectin (Paridah *et al.*, 2011). Pectic substances i.e. acidic polysaccharides are present in form of calcium and magnesium pectate in middle lamella of cell (Jayani *et al.*, 2005; Murad and Azzaz 2011; Chiliveri *et al.*, 2016). Pectins are composed of multiple units of galacturonic acid which are connected through α -1,4 glycosidic bond, with a side chain of simple monosaccharides (Gummadi and Kumar, 2006). Traditionally retting is performed by pectinolytic enzymes secreted by microorganisms (Tamburini *et al.*, 2003). Quality of fiber depends on nature of retting. Over retting by microorganisms degrades the fibers (cellulose) while incomplete removal of fiber from stem due to under retting produces low quality fiber (Banik *et al.*, 2003).

Pectinases are mainly consists three enzymes viz. polymethylsterase, polygalacturonase and pectate lyase (Jayani *et al.*, 2005, Abbasi and Fazaalipoor, 2010, Prathyusha and Suneetha, 2011). Though according to Das *et al.* (2012), four enzyme i.e. polymethylsterase, polygalacturonase, pectate lyase and pectin lyase are belonging to group "Pectinase". Methylsterases converts the pectin substrate to pectate by eliminating the methoxyl group from pectin (Kohli *et al.*, 2015) while degradation of α (1-4)-glycosidic linkage between the galacturonic acid molecules is carried out by polygalacturonase (Prathyusha and Suneetha, 2011). Pectate lyase degrades pectin by removing oligosaccharides of α (1-4) linked galacturonic acid molecules. Various literature suggested that polygalacturonase (Chesson, 1978; Akin *et al.*, 1998; Zhang *et al.*, 2000; Tamburini *et al.*, 2003) and pectin lyase (Soriano *et al.*, 2005; Das *et al.*, 2012; Das *et al.*, 2015) are the primary retting agent. During retting, pectic components are changed into soluble pectin followed by pectic acid in presence of pectinase and pectase respectively (Bhuiyan *et al.*, 1979; Haq *et al.*, 2001a). The pectic are converted to glutamate in presence of pectinase. In addition to pectinolytic activity, xylanase activity of retting microorganisms is improved the fiber quality (Gomes *et al.*, 1992). Improper removal of the non-fiber components like hemicelluloses converts the jute fiber considerably softer for finer spinning (Ray *et al.*, 2015). Hence microorganism having high pectinolytic and xylanase activity along with low/least cellulase activity can be considered as efficient retting microbes to get good quality fiber (Das *et al.*, 2018).

Microorganisms in Jute retting:

Study on the role of microorganisms related to jute retting started at early nineteenth century. Prior to 1950s, jute retting based experiments were focused on influence of isolated aerobic microorganisms involved on retting of jute stem by conventional culture based approaches. During this phase, Debsharma (1946) reported several notable bacterial strains like *Bacillus subtilis*, *Bacillus*

mesentricus and *Bacillus macreans* for effective jute retting. Barinova (1946) sketched some quantitative assay about pectin fermentation by *Clostridium felsineum* and *Bacillus acetoethylicus*. Whereas Potter and McCoy (1952, 1955) checked the retting ability of *Clostridium felsineum* and *Bacillus polymyxa*. Ali (1958) isolated a spore forming rod shaped bacteria and reported as *Bacillus polymyxa*, and got retted jute stem within 10 days in laboratory condition. Betrabet and Bhat (1958) tried to explore retting efficiency of the microbes of the genera *Pseudomonas*, *Bacillus*, *Aerobacter* and *Flavobacterium* for jute under retting tank condition. Chakravarty *et al.* (1962) clearly reported and identified some fastidious fungal species which grown repeatedly in usual fungal medium from retting water were *Aspergillus terreus*, *Pacilomyces varioti*, *Penicillium citrinium*. Whereas Ahmed (1963) reported some fungi of phylum Ascomycota *i.e.* *Penicillium* sp., *Aspergillus niger*, *Macrophomina phaseolina*, *Chaetomium* sp., *Phoma* sp. and *Mucor* sp. of phylum Zygomycota for efficient retting. Alam (1970) isolated some anaerobes from retting water and reported those species as *Clostridium tertium aurantibutyricum*, *C. felsineum*. Haque *et al.* (2002) investigated the community structure of microbes of different stages of jute retting period. Munsri and Chatto (2008) analyzed the bacterial diversity of jute retting ponds located at southern region of West Bengal using metagenomic approaches and found seven groups of bacterial species like proteobacteria (41%), Firmicutes (12%), *Cytophaga-Flexibacter-Bacteroidetes* (7%), *Verrucomicrobia* (5%), *Acidobacteria* (5%), *Chlorobiales* (5%), and *Actinobacteria* (2%). On the other side Akhtar and Mandal (1996) elaborated the population structure of rhizosphere and retting ponds of jute and other fibrous plants and they concluded that fungal diversity was dominant on post retting water. Das *et al.* (2012) studied in details the diversity of pectinolytic bacteria from jute retting ponds and they found the variation in concentration for polygalactouronase, pectin lyase, as well as xylanase. Quantitative analyses of microbial jute retting enzymes were also studied by Ray *et al.* (2015). Keeping view in role of microorganisms in retting, scientists are engaged to identify effective retting microorganisms though reports are very less. Most of effective retting microorganisms identified till date either based on Bergey's Manual or Biolog analysis or 16S rDNA sequencing (Table 1). It is very much important to know the kinetics study of those enzymes and from that knowledge the optimum time period, temperature, pH can be standardized. This type of experiments was done different natural fibre crops like kenaf, hemp, mestha but in case of jute these types of research reports were very few (Basu *et al.*, 2009; Juarez *et al.*, 2009; Yu and Yu, 2007 and Zhang *et al.*, 2000). Chiliveri *et al.* (2016) reported an UV mutant *Bacillus tequilensis* strain SV-11-UV-37 which has highly efficient polygalactouronase, pectin lyase and xylanase

producing organisms and developed a solid state fermentation technique to produce high quality of jute fiber in cost-effective way. In another report, Nath *et al.* (2017) showed that three effective polygalactouronase and pectin lyase secreting microbes solely as well as in combination developed the overall retting process and produced a good quality of fibre. Das *et al.* (2018) used various microbial consortium and clearly showed high quality of fibre production with better strength and fineness using dry retting technique. Whereas Vijayraghaban and Stephen (2012) experimentally construct sequencing batch reactor which using aerobic microbial jute retting. In this method retting period was characterized based on tenacity and modulus, after 25 days of retting the quality of fiber is the best. After retting the liquor of retting was characterized and the structure of microbes was identified which showed species of *Bacillus*, *Clostridium*, *Aspergillus* and *Mucor* was predominant.

The glories of jute based industry declined due its low quality fiber and increase the use of synthetic fibers. So there is need to improve the fiber quality with most updated techniques. Retting is the quality determining factor of jute. Currently most problematic issue of jute retting is scarcity of water. In spite of high pectinolytic activity, improper retting leads to low quality jute under low water content. So dew retting or ribbon retting is going to be an alternative of conventional retting in upcoming time. There need to do multilocal trial of effective pectinolytic microorganisms to justify the activity against the biotic and abiotic factors. Till date the research on microbial jute retting is restricted to single microorganisms, need to explore the combined effect of retting microorganisms. Bioreactor based retting is also found most cost effective and profitable in comparison to others techniques.

REFERENCES

- Abbasi, H. and Fazaelpoor, M.H. 2010. Pectinase production in a defined medium using surface culture fermentation. *Int. J. Ind. Chem.*, **1**:5-10
- Ahmad, M. 1963. Studies on Jute Retting Bacteria. *J. Appl. Microbiol.*, **26**(2): 117-26
- Ahmed, Z. and Akhter, F. 2001. Jute Retting: An Overview. *Online J. Biol. Sci.*, **1**(7):685-88
- Ahmed, Z. and Nizam, S. A. 2008. Jute - Microbiological & Biochem. Res. *Pl. Tissue Cult. & Biotech.*, **18**(2): 197-220
- Akhter, F. and Mandal, R. 1996. Study of bacterial population in the Rhizosphere of Jute and allied fibrous plants. *Bangladesh J. Microbiol.*, **13**: 35-42
- Akin, D. E., Rigsby, L. L., Henriksson, G. and Eriksson, K. E. 1998. Structural effects on flax stems of three potential retting fungi. *Text. Res. J.*, **68**(7): 515-19
- Alam, S.M. 1970. Jute retting bacteria from certain ditches of East Pakistan. *Pakistan J. Sci. Ind. Res.*, **12**: 229-31

- Ali, M. M. 1958. Aerobic bacteria involved in the retting of jute. *Appl. Microbiol.*, **6**(2): 87-89
- Ali, M. M. and Alam, S. 1973. Effect of different pH values on jute retting. *Bangladesh J. Bot.*, **2**: 19-23
- Ali, M. M., Alam, S., Eshaque, A. K. M. and Khandaker, A. L. 1976. Studies on the mechanization of jute retting. *Bangladesh J. Jute Fibre Res.*, **1**: 61-70.
- Ali, M. R., Kozan, O., Rahman, A., Islam, K. T. and Hossain, M. I. 2015. Jute retting process: present practice and problems in Bangladesh. *Agric. Eng. Int.: CIGR J.*, **17**(2): 243-47
- Banerjee, B. 1955. Jute—Especially as produced in west Bengal. *Econ. Bot.*, **9**(2): 151-174
- Banik, S. 2016. Fungal dry retting—An ecofriendly and water saving technology for retting of jute. *Indian J. Fibre Text.*, **41**: 212-16
- Banik, S. and Ghosh, S. N. 2008. Pectinolytic activity of microorganisms in piling of jute. *Indian J. Fibre Text.*, **33**: 151-56
- Banik, S., Basak, M. K. and Sil, S. C. 2007. Effect of inoculation of pectinolytic mixed bacterial culture on improvement of ribbon retting of jute and kenaf. *J. Nat. Fibers.*, **4**(2): 33-50
- Banik, S., Basak, M. K., Paul, D., Nayak, P., Sardar, D., Sil, S. C. and Ghosh, A. 2003. Ribbon retting of jute—a prospective and eco-friendly method for improvement of fibre quality. *Ind. Crops Prod.*, **17**(3):183-90
- Barinova, S. A. 1946. On the decomposition of pectin by microbial ferments. *Mikrobiologiya (USSR)*, **15**: 313-18
- Basak, M. K., Bhaduri, S. K., Banik, S., Kundu, S. K. and Sardar, D. 1998. Some aspects of biochemical changes associated with retting of green jute plants. *Proc. Intl. seminar on jute and allied fibres—changing global scenario in 5–6 February, 1998, Calcutta*, pp 105–108.
- Basu, S., Saha, M. N., Chattopadhyay, D. and Chakrabarti, K. 2009. Large-scale degumming of ramie fibre using a newly isolated *Bacillus pumilus* DKS1 with high pectate lyase activity. *J. Ind. Microbiol. Biot.*, **36**(2): 239-45
- Betrabet, S. M. and Bhat, J. V. 1958. Pectin decomposition by species of *Pseudomonas* and their role in the retting of Malvaceous plants. *Appl. Microbiol.*, **6**(2): 89-93
- Bhuiyan, A. M., Ali, M. and Rahman, M. 1979. Studies on changes in chemical composition of jute fibre during retting. *Bangladesh J. Jute Fiber Res.*, **4**: 33-39
- Chakravarty, T., Bose, R. G. and Basu, S. N. 1962. Fungi growing on jute fabrics deteriorating under weather exposure and in storage. *Appl. Environ. Microbiol.*, **10**(5): 441-47
- Chapke, R.R. and Borkar, U.N. 2011. Improved retting technology for quality jute fibre production. *Indian Farming, ICAR.* **60**: 23-25
- Chesson, A. 1978. The maceration of linen flax under anaerobic conditions. *J. Appl. Bacteriol.*, **45**(2): 219-30
- Chiliveri, S. R., Koti, S. and Linga, V. R. 2016. Retting and degumming of natural fibers by pectinolytic enzymes produced from *Bacillus tequilensis* SV11-UV37 using solid state fermentation. *Springer Plus*, **5**(1): 559.
- Das, B., Chakrabarti, K., Ghosh, S., Majumdar, B., Tripathi, S. and Chakraborty, A. 2012. Effect of efficient pectinolytic bacterial isolates on retting and fibre quality of jute. *Ind. Crops Prod.*, **36**(1): 415-19
- Das, B., Chakrabarti, K., Tripathi, S. and Chakraborty, A. 2014. Review of some factors influencing jute fiber quality. *J. Nat. Fibers.*, **11**(3): 268-81
- Das, S., Majumdar, B. and Saha, A. R. 2015. Biodegradation of plant pectin and hemicelluloses with three novel *Bacillus pumilus* strains and their combined application for quality jute fibre production. *Agricul. Res.*, **4**(4): 354-64
- Das, S., Majumdar, B., Saha, A. R., Sarkar, S., Jha, S. K., Sarkar, S. K. and Saha, R. 2018. Comparative study of conventional and improved retting of jute with microbial formulation. *Proc. Natl. Acad. Sci. India Sect. B Biol. Sci.*, **88**(4): 1351-57
- Deb, P.K. 1954. *A comparative study of jute*, K.M. Deb Publisher, Calcutta, pp. 207
- Debsharma, G. D. 1946. Biochemical investigations on jute retting. *Indian J. Agric. Sci.*, **16**: 453-58
- Duan, L., Yu, W. and Li, Z. 2017. Analysis of structural changes in jute fibers after peracetic acid treatment. *J Eng. Fiber Fabr.*, **12**(1): 33-42
- Ghosh, S. K., Bhattacharyya, R. and Mondal, M. M. 2014. A review on jute geotextile-Part 1. *Int. J. Res. Eng. Technol.*, **3**(2): 378-86
- Gomes, I., Saha, R. K., Mohiuddin, G. and Hoq, M. M. 1992. Isolation and characterization of a cellulase-free pectinolytic and hemicellulolytic thermophilic fungus. *World J. Microb. Biot.*, **8**(6):589-92
- Gummadi, S. N. and Kumar, D. S. 2006. Enhanced production of pectin lyase and pectate lyase by *Debaryomyces nepalensis* in submerged fermentation by statistical methods. *Am. J. Food Technol.*, **1**(1): 19-33
- Haque, M. S., Ahmed, Z., Akhter, F., Asaduzzaman, M., Rahman, M. M. and Hannan, M. A. 2001. Comparative studies of retting properties of different released varieties of jute. *OnLine J. Biol. Sci.*, **1**: 998-1000
- Haque, M. S., Ahmed, Z., Asaduzzaman, M., Quashem, M. A. and Akhter, F. 2002. Distribution and activity of microbial population for jute retting and their impact on water of jute growing areas of Bangladesh. *Pakistan J. Biol. Sci.*, **5**(6): 704-706
- Haque, M. S., Asaduzzaman, M., Akhter, F. and Ahmed, Z. 2001a. Retting of green jute ribbons (*Corchorus capsularis* var. CVL-1) with fungal culture. *Online J. Biol. Sci.*, **1**: 1012-14
- http://ministryoftextiles.gov.in/pdf/ar03_c11.pdf

- Islam, M. M. and Rahman, M. M. 2013. Advances in jute and allied fibres post-harvest processing technologies in Bangladesh: Adoption constraints, prospect and future thrust. *Research WebPub*, **1**(2): 20-30
- Islam, M. S. and Ahmed, S. K. 2012. The impacts of jute on environment: An analytical review of Bangladesh. *J. Env. Earth Sci.*, **2**(5): 24-31
- Jahan, M. S., Rahman, J. N. M. M., Islam, M. and Quaiyyum, M. A. 2016. Chemical characteristics of ribbon retted jute and its effect on pulping and papermaking properties. *Ind. Crops Prod.*, **84**:116-20
- Jahan, M. S., Saeed, A., He, Z. and Ni, Y. 2011. Jute as raw material for the preparation of microcrystalline cellulose. *Cellulose*, **18**(2): 451-59
- Jalaluddin, M. 1965. Studies in jute retting aerobic bacteria. *Econ. Bot.*, **19**(4): 384-93
- Jayani, R. S., Saxena, S. and Gupta, R. 2005. Microbial pectinolytic enzymes: a review. *Process Biochem.*, **40**(9): 2931-44
- Juárez, A. V., Dreyer, J., Göpel, P. K., Koschke, N., Frank, D., Märkl, H. and Müller, R. 2009. Characterisation of a new thermoalkaliphilic bacterium for the production of high-quality hemp fibres, *Geobacillus thermoglucosidasius* strain PB94A. *Appl. Microbiol. Biotechnol.*, **83**(3): 521-27
- Kohli, P., Kalia, M. and Gupta, R. 2015. Pectin methylesterases: a review. *J. Bioprocess Biotech.*, **5**(5): 1
- Kundu, B. C. 1956. Jute—world's foremost bast fibre, II. Technology, marketing, production and utilization. *Econ. Bot.*, **10**(3): 203-240
- Kundu, B. C., Basak, K. C. and Sarkar, P. B. 1952, *Jute in India — A monograph*. Ind. Cent. Jute. Com. Calcutta. p112
- Majumdar, B., Das, S. and Saha, M. N. 2008. Monitoring of microbial status of retting water and soil of some jute growing areas of South Bengal. *Proc. Intl. symp. on jute and allied fibres production, utilization and marketing* - January, 2008, Kolkata. 66
- Mian, M.H.A., Samad, M.A. and Sarker, N.N. 1996. Comparative study on the physico-mechanical properties of jute, kenaf and mesta- Part-V, *Bangladesh J. Jute Fib. Res.*, **21**: 71-80
- Munshi, T. K. and Chattoo, B. B. 2008. Bacterial population structure of the jute-retting environment. *Microb. Ecol.*, **56**(2): 270-82
- Murad, H. A. and Azzaz, H. H. 2011. Microbial pectinases and ruminant nutrition. *Res. J. Microbiol.*, **6**(3): 246-69
- Nath, M., Majumdar, B., Das, S., Mazumdar, S. P., Saha, A. R., and Sarkar, S. 2017. Optimization of Fermentation Conditions for Pectin Degrading Enzyme Production by Pectinolytic Microbial Consortia Used for Jute Retting. *Int.J.Curr.Microbiol.App.Sci.* **6**(11): 925-31
- Paridah, M. T., Basher, A. B., SaifulAzry, S. and Ahmed, Z. 2011. Retting process of some bast plant fibres and its effect on fibre quality: A review. *BioResources*, **6**(4): 5260-81
- Potter, L. F. and McCoy, E. 1952. The fermentation of pectin and pectic acid by *Clostridium felsineum*. *J. Bacteriol.*, **64**(5): 701-08
- Potter, L. F. and McCoy, E. 1955. The fermentation of pectin and pectic acid by *Bacillus polymyxa*. *J. Bacteriol.*, **70**(6): 656-62
- Prathyusha, K. and Suneetha, V. 2011. Bacterial pectinases and their potent biotechnological application in fruit processing/juice production industry: a review. *J. Phytol.*, **3**(6): 16-19
- Rahman, S., Kazal, M.M.H., Begum, I. A. and Alam, M.J. 2017. Exploring the future potential of jute in Bangladesh. *Agriculture*, **7**(12): 96
- Ray, D. P., Banerjee, P. and Nag, D. 2015a. Improvement of jute retting processes in India in the context of water scarce situation. *Int. J. bioresource Sci.*, **2**(2): 101-10
- Ray, D. P., Saha, S. C., Sarkar, A. and Ghosh, R. K. 2016. Production of quality jute fibre through accelerated retting. *International J. Bioresource Sci.*, **3**(2): 57-65
- Ray, S. S., Das, S., Ali, M. N., Yeasmin, L. and Majumder, B. 2015. Biochemical characterization and biolig based identification of efficient jute retting bacterial isolates from retting water. *J. Phytol.*, **7**(1): 32-38
- Sarkar, S. and Sengupta, K. 2015. Comprehensive Technique for Jute Fibre Retting. *Int. J. bio-resource environ. agric. sci.*, **6**(1): 170-75
- Soriano, M., Diaz, P. and Pastor, F. J. 2005. Pectinolytic systems of two aerobic sporogenous bacterial strains with high activity on pectin. *Curr. Microbiol.*, **50**(2): 114-18
- Tamburini, E., León, A. G., Perito, B. and Mastromei, G. 2003. Characterization of bacterial pectinolytic strains involved in the water retting process. *Environ. Microbiol.*, **5**(9): 730-36
- Vijayaraghavan, K. and Stephen, D. N. 2012. Microbial Retting of Jute Bast Fibre Using Aerobic Sequencing Batch Reactor. *Asian J. Water, Env. Pollu.*, **9**(2): 109-17
- Yu, H. and Yu, C. 2007. Study on microbe retting of kenaf fiber. *Enzyme Microb. Tech.*, **40**(7):1806-09
- Zhang, J., Henriksson, G. and Johansson, G. 2000. Polygalacturonase is the key component in enzymatic retting of flax. *J. Biotechnol.*, **81**(1):85-89