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Mechanization of fibre extraction: an eco-friendly alternative method of jute retting

Mst. Aleya Nasreen[1], Md. Mahabub Ali[1], Selina Akhter[1], Tahmina[1], Md. Anisur Rahman Dayan[2] and Md. Moslem Uddin[2]

[1]Biochemistry and Microbiology Department, Technology Wing, Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka-1207, Bangladesh
[2]Textile Physics Division, Technology Wing, Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka-1207, Bangladesh

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For any information:
dr.nasreenbjri@gmail.com

ABSTRACT

Jute retting has become a major obstacle for cultivation of jute due to water scarcity. Not only that, the water retting generates waste water and causes environmental pollution. This experiment was conducted to extract fibre through a mechanical process instead of extracting traditional water retting to overcome the problem. Machine extraction and water retting methods were applied to non-retted ribbons. Physico- chemical properties were then determined of the extracted fibre samples. The promising result obtained that the fibre extraction from ribbon is possible by the developed fibre extractor machine. Machine extracted fibre of the bottom portion shows similar strength and luster property like water retted fibre of the bottom. Middle portion of the machine extracted fibre showed a significantly higher luster property compared to water retted middle portion. Machine extracted fibres were coarse compared to water retted fibre. Water retting process produced finer quality fibre. Machine extracted fibres contain lower cellulose, higher hemicellulose and higher lignin compared to water retted fibre. These results show the possibility of developing alternative bast fibre extraction processes employing machine not undergoing water retting method.

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I. Introduction

Jute fibre is considered as cheap textile fibres with a lower amount of cumulative energy required for the production of fibre compared to cotton and kenaf (La Rosa and Grammatikos, 2019). It grows well in tropical and sub-tropical regions throughout the world. However, India, Bangladesh, China, Nepal and Thailand are major jute growing countries contributing about 95% of world jute production (FAO 2018). Jute fibre is extensively used for manufacturing packaging materials for various agricultural commodities and diversified fashion, crafts and technical products (Basu et al., 2005). Extraction of fibre from jute plants is water-based microbial process where jute plants are immersed in slow flowing water in canals, tanks, ponds or ditches and it takes 18-21 days to degrade cementing materials pectin and lignin and gummy substance hemicellulose (Hasan et al., 2020). Moreover, the traditional retting process is not environmentally friendly and requires large amounts of water. About 432 cubic meters of water is required to rot per metric ton of raw jute through a water-retting microbial process (Huda et al., 2012). In this process, microbial activity takes place continuously that leading to loosen fibres from the woody stem (Basak et al., 1998) as a result, huge amounts of biomass are decomposed (Banik et al., 1993) and create pollution of water that used for retting and the surrounding environment. This traditional retting process produces bad smell and changes in the color of the water and affects the water quality, fish cultivation and increased environmental pollution (Ali et al., 2015). Often jute farmers face water crisis during harvest season due to late onset of rain, drying of river or water bodies. Ideal retting condition does not prevail most of the time. To make ease the retting process ribbon retting is trying to introduce at farmer's level. Ribbons are separated from the stem of matured jute plant by ribbonner then separated ribbons are coiled and allowed to ret under limited water. It requires less water and can reduce retting time, but still need microbial process. Farmers are still reluctant to adopt ribbon retting technology (Anonymous, 2013). Therefore, the urgency of demand an alternative way to extract fibre without water based microbiological process. Here, we developed electro-mechanical process to extract high quality fibre from ribbon without undergoing retting process. Ribbons (decorticated bark) are thick, strong, non-divisible and heavily attached by remnants of other plant tissues. The action of blade rotation removes these remnant tissues at high speed during the operating machine. Green ribbons are cut into small pieces and placed in machine with water. After 10-15 minutes, fibres are separated from green ribbon for subsequent use. This mechanization process may help to reduce time, labour and water. The process causes no environmental pollution. This fibre may be suitable for making pulp and paper, composite, and blended yarn with other natural fibre like cotton, ramie, banana, coir etc. for the production of diversified products. To the best of our knowledge, this is the first attempt to extract fibre from jute ribbon by machine.

II. Materials and Methods

Fibre extractor

Microbiology & Biochemistry Department of Bangladesh Jute Research Institute, Dhaka designed and developed a machine for separating fibre from jute ribbon with the help of Mirpur Agricultural Workshop and Training School (MAWTS), 1/C-1/A, Pallabi, Mirpur, Dhaka-1216 (Figure 01a,b). The prototype features a blender similar to the existing machines. The device comprises a frame, four blades inside the bucket and an electric motor (Motor power: 1 HP, Power supply: 220V and Power retting: 0.75KW). The production capacity of the machine is 2-2.5 kg per hrs and rotation speed 2500 rpm.

Figure 01(a) Fibre extractor machine

Figure 01(b) Inner side view showing blade

Fibre extraction using extractor machine

120 days old jute plants (*Corchorus olitorius*, variety O-9897) with an average height of 3.15 m and diameter of 19 mm were collected from Jute Agricultural Experimental Station, Manikganj, Bangladesh Jute Research Institute and then separated ribbon from the jute plant. Ribbons were cut into 4″-6″ long

pieces and placed in the machine with water. Ribbon and water ratio was 1:10. Then the machine operates for 10/15 minutes for separating fibre. Extracted fibres were washed, dried and preserved (Figure 02) in polythene packet for next physico-chemical properties studies.

Figure 02. Image of machine extracted fibre and water retted fibre. a) Machine extracted fibre, bottom part; b) Machine extracted fibre, middle part; c) Machine extracted fibre, top part; d) Water retted fibre, bottom part; d) Water retted fibre, middle part; e) Water retted fibre, top part.

Fibre extraction by water retting

Green ribbons were separated from 120 days aged defoliated jute plant (*Corchorus olitorius*, variety O-9897) with an average height of 3.15 m and diameter 19 mm by a ribboner (decorticator) machine developed by BJRI. Green ribbon of 10 kg was submerged in 50 L of concrete water tank and allowed to complete retting for 20 days. After completion of retting, fibres were washed and dried for next physico-chemical properties studies.

Fibre bundle strength

Stelometer tester was used to determine the fibre bundle strength in gm/tex, which is performed tests according to test methods of ASTMD1445. Well combed fibres are placed on the pair of small clamp using zero gauge length and all protruding ends were sheared off evenly. The fibre clump is inserted at the top of the pendulum and tension was applied to break the fibres. The broken bundles fibres were weighted by precision balance. The breaking force and weight are used in the following equation to determine the strength.

$$T = f/m \times 11.81^{*}$$

Where,

f = breaking force in Kp,
m = mass of the tested fibre bundle in milligrams,
T = tenacity in gm/tex,
*11.81 stand for the length of samples in millimeters

Fineness

Both machine extracted and water retting extracted fibres diameter were measured using Microscope (YGOO2C, Panasonic WV-CP310/CH, Japan). Single fibre was placed on the glass slide for the microscopic measurement, fibre diameter was measured at different 10 points of the fibre. Ten fibres replications were used for each sample.

Brightness / Lustre

The brightness percentage of machine extracted fibre and water retted fibre was determined by PHOTOVOLT (Model 577 Reflection meter, USA). The green tristimulus filter is used to determine the lightness or whiteness of a colour irrespective of hue as it most closely transmits light detectable by human eye. Green filter transmittance (LaCorix range 450 -620) and transmittance (peak) 550nm.

Chemical component analysis

Chemical components such as cellulose, hemicellulose and lignin percentage of machine extracted fibre and retted fibre were determined by Thermogravimetric analyzer. The thermal degradation behavior of cellulose, hemicellulose and lignin were analyzed by a Thermogravimetric analyzer (ELTRA THERMOSTEP, Germany) following ASTM standard. The temperature was calibrated before the experiment. The extracted fibre samples (minimum 400mg) were placed in alumina crucible for testing and the process was carried out in an inert atmosphere with nitrogen gas and heated from room temperature to 500°C at a dynamic heating rate of 10°C /min. The measurement of hemicellulose was carried out in the temperature range from room temperature 315°C, cellulose from room temperature to 475°C and lignin was measured in the temperature from room temperature to 900°C.

Data Analysis

Data were subjected to analysis of variance using MSTAT-C (ver. 6.0, Michigan State University, East Lansing, MI) and means comparisons for the significantly different variables were made among treatments using Least Significant Differences (LSD) test at 0.05 level of significance.

III. Results and Discussion

Fibre bundle strength

The analysis of variance shows that fibre strength significantly influenced the water retting fibre compared to machine extracted fibre (Table 01). The bottom portion of machine extracted fibre shows slightly higher strength compared to water retting extracted fibre, but the difference is not significant with water retted bottom portion of the fibre. But top and middle portion of the water retted fibre shows higher strength than machine extracted fibre (Table 02). Gummy and waxy substances from the machine extracted fibre are removed by the blade's mechanical action of speedy rotation. In water retted fibre, gummy and waxy substances were removed through the microbial process while fibers were completely submerged in concrete tank water for 20 days. Fibre length was not shortened by water retting and so the intact fibre is capable of transfer load that contribute high strength (Amel et al., 2013). In another study, Morrison et al. (2000) observed higher strength property of flax fibre from water retted fibre than dew retted fibre and mentioned that this happened due to the conservation of cross-linking fractions. Van der Westhuisen (2018) investigated six retting methods, namely enzymatic retting, dew retting, water retting, NaCl retting, Urea retting and NaOH retting for some kenaf varieties and reported that water retting produces the highest strength for all kenaf varieties.

Table 01. Analysis of variance of fibre bundle strength, brightness and fineness.

Part of fibre	Fibre bundle strength		Fibre brightness		Fibre fineness	
	F value	P value	F value	P value	F value	P value
Bottom	1.5900	0.3345	17.6781	0.0592	252.8851	0.0039
Middle	18.1793	0.0508	23.0620	0.0407	279.3940	0.0036
Top	29.2637	0.0325	25.5265	0.0370	2399.0998	0.0004

Fibre brightness /luster

Brightness of fibre affects significantly by the method of fibre extraction (Table 01). Brightness property differed in a different portion of the plant between machine extracted and water retted fibre. Brightness does not differ significantly in bottom portion of machine extracted fibre and water retted fibre (Table 02). Middle portion of machine extracted fibre showed more luster property compared to water retted fibre (Table 02). In top portion, water retted fibre showed more luster compared to machine extracted fibre (Table 02). Top portion of the plant is comparatively softer than the other portion of the plant, that’s why high speed rotation of the blade may break or disarrange the fibrillary orientation. Bag and Ray (1978) commented on differences in luster in jute samples due to differences in fibrillar orientation, which in turn is the average effect of the arrangement of the fibrils in the cell wall. Variation of luster property in bottom and middle portion indicate machine extracted fibre may yield similar or more bright fibre compared to water retted fibre. So improvement of machine may produce good lusterous fibre.

Fineness

Fibre fineness significantly affected on fibre extraction method in all parts of the sample (Table 01). Machine extraction process yield coarse fibre compared to the fibre produced through water retting. This machine may not remove uniformly all the non-cellulosic material of the fibre, especially lignin and hemicellulose. The better fineness was observed in water retting fibre, including bottom, middle and top portion of fibre (Table 02). Fibre fineness is an important property that influences fibre spinnability and qualities of end-use yarns, fabrics and composites. It is universally accepted that spinnability would be higher if the fibre is finer (Grishanov et al., 2006). Fineness property of the machine extracted fibre may be treated and improved. Jute fibre reduces the coarseness and rigidity of the fibres and renders the distinctly softer by treatment with polysaccharide degrading enzyme (Chakrabarti et al., 1991; Kundu et al., 1993).

Table 02. Physical properties comparison of machine extracted fibre and water retted fibre.

Method of fibre extract	Strength (gm/tex)			Brightness (%)			Fineness (μm)		
	Bottom	Middle	Top	Bottom	Middle	Top	Bottom	Middle	Top
Machine extract	35.01± 0.84	31.94± 0.89	32.81± 0.40	26.56± 0.68	33.34± 0.65	28.77± 0.90	43.64± 2.76	32.41± 0.67	22.70± 1.29
Water Retting	34.88± 0.55	35.21± 0.60	33.63± 0.64	30.81± 1.20	31.31± 0.71	32.07± 0.78	35.83± 0.45	24.72± 0.61	16.96± 0.87
Significance level	ns	*	*	ns	*	*	*	*	*

ns, Non-significance at 0.05% level; * Significance at 0.05% level

Chemical component of extracted fibre

The analysis of variance shows that cellulose, hemicellulose and lignin content of extracted fibre significantly influenced the methods of fibre extraction (Table 03). The cellulose and hemicellulose were higher in water retted fibre, but the amount of lignin was significantly lower in water retted fibre (Table 04). There are variations in cellulose, hemicellulose and lignin content in top, middle and bottom portions of the ribbon. Cellulose content decrease in machine extracted fibre from bottom to top and highest cellulose content was in the middle portion and lowest in the top from water retted fibre. The lowest amount of hemicellulose was in the bottom, but the middle and top have almost similar in machine extracted fibre. In water retted fibre, hemicellulose content was highest in bottom and almost similar in middle and top. Lignin content was decreasing from bottom to top in both machine extracted and water retted fibre. Bottom portion to top portion of the plant, lignin content gradually decreases and α-cellulose content increases in water retted jute fibre compared to ribbon retted fibre (Jahan et al., 2016). Pentosan content was higher, and lignin and cellulose content were lower in ribbon retting than traditional water retting jute fibre (Jahan et al., 2008). Batra (2007) reported that retting method influences chemical composition significantly.

Table 3. Analysis of variance of cellulose, hemicellulose and lignin content of fibre

Part of fibre	Cellulose		Hemicellulose		Lignin	
	F value	P value	F value	P value	F value	P value
Bottom	21.3893	0.0437	21.0369	0.0444	92.1914	0.0107
Middle	8406.0131	0.0001	52.6377	0.0185	158.2602	0.0063
Top	24.8543	0.0495	22.0313	0.0484	289.5764	0.0034

Table 04. Chemical constituents as percentage of machine extracted and water retted jute fibre

Method of fibre extract	Cellulose			Hemicellulose			Lignin		
	Bottom	Middle	Top	Bottom	Middle	Top	Bottom	Middle	Top
Machine extract	57.74± 0.25	52.66± 0.21	50.36± 0.38	27.21± 0.33	29.56± 0.46	29.30± 0.19	19.16± 0.26	18.13± 0.24	16.01± 0.49
Water Retting	58.60± 0.27	61.37± 0.31	57.63± 0.64	31.09± 0.53	26.86± 0.09	26.59± 0.46	14.09± 0.05	13.71± 0.42	12.11± 0.18
Significance level	**	**	**	*	*	*	*	**	**

* Significance at 0.05% level; ** Significance at 0.01% level

IV. Conclusion

In this study, an alternative way to extract fibre from ribbon/bark was developed to not require a water-based microbiological process. The extracted fibres were also compared with water based retting fibre. The findings indicate that it is possible to separate fibre from ribbon by the electro-mechanical process. Strength and lustre properties of the machine extracted fibre quality is more or less similar to water retted fibre. There is scope to improve the machine for large scale fibre extraction. From the perspective of practical application, it is mandatory to proceed with field trials at a large scale with a larger machine capacity. This first work of fibre extraction process by machine proved the possibility as retting alternative to some extent. So this research can be the future focus of the mechanization of fibre extraction as an alternative retting.

References

[1]. Ali, M. R., Kozan, O., Rahman, A., Islam, K. T. and Hossain, M. I. (2015). Jute retting process: present practice and problems in Bangladesh. Agricultural Engineering International, 17(2), 243-247.

[2]. Amel, B. A., Paridah, M. T., Sudin, R., Anwer, U. M. K. and Hussein, A. S. (2013). Effect of fibre extraction method on some properties of kenaf bast fibre. Industrial Crops and Products, 46, 117-123. https://doi.org/10.1016/j.indcrop.2012.12.015

[3]. Anonymous (2013). Ribbon retting fails to attract jute farmers. The Daily Star, August 30, 2013. https://www.thedailystar.net/news/ribbon-retting-fails-to-attract-jute-farmers.

[4]. Bag, S. C. and Ray, P. K. (1978). The luster of jute fibre in relation to its fine structure. Textile Research Journal, 48(12), 710-712. https://doi.org/10.1177/004051757804801207

[5]. Banik, A., Sen, M. and Sen, S. P. (1993). Methane Emission from Jute-Retting Tanks. Ecological Engineering, (2), 73-79. https://doi.org/10.1016/0925-8574(93)90028-E

[6]. 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. Proceedings of Contaminated with Dye and Other Organics. Bioresources Technology, 96, 1919–1928.

[7]. Basu, G., Sinha, A. K. and Chattopadhyay, S. N. (2005). Properties of Jute Based Ternary Blended Bulked Yarns. Man-Made Textiles in India. 48, 350-353.

[8]. Batra, S. K. (1985). Other long vegetable fibres: abaca, banana, sisal, henequen, flax, ramie, hemp and sun and coir. Handbook of fiber science and technology, 4, 727-807.

[9]. Chakrabarti, S. K., Ghosh, B. S., Kundu, A. B. and Ghosh, B. L. (1991). Improvement in brightness and fineness of jute fibre by treatment with EDTA and polysaccharide-degrading enzymes. Indian Journal of Fibre Textiles Research, 16(2), 154-158.

[10]. FAO (2018). Statistical Bulletin. Food and Agriculture Organization of the United Nations. Rome, Italy.

[11]. Grishanov, S. A., Hardwood, R. J. and Booth, I. (2006). A method of estimating single fibre fineness using data from laser scan system. Industrial Crops and Products, 23, 273-287. https://doi.org/10.1016/j.indcrop.2005.08.003

[12]. Hasan, R., Aktar, N., Kabir, S. M. T., Honi, U., Halim, A., Islam, R., Sarker, M. D. H., Haque, M. S., Alam, M. M. and Islam, M. S. (2020). Pectinolytic Bacterial Consortia Reduce Jute Retting Period and Improve Fibre Quality. Scientific Reports, 10, 5174. https://doi.org/10.1038/s41598-020-61898-z

[13]. Huda, H. N., Tajuddin, R. M., Ahmad, Z. and Nazrin, O. M. (2012*).* Determination of Optimum Debark Time In Retting Process of Kenaf Fibre Production. International Sustainability and Civil Engineering Journal, 1(2), 14–18.

[14]. Jahan, M. S., Kanna, G. H., Mun, S. P. and Chowdhury, D. N. (2008). Variation of chemical pulp ability within jute plant (*Corchorus capsularis*). Industrial Crops and Products, 28(2), 199-205. https://doi.org/10.1016/j.indcrop.2008.02.013

[15]. Jahan, M. S., Nayeem, J., Rahman, M. M., Islam, M. and Quaiyyum, M. A. (2016). Chemical characteristics of ribbon retted jute and its effect on pulping and paper making properties. Industrial Crops and Products, 84, 116-120. https://doi.org/10.1016/j.indcrop.2016.01.054

[16]. Kundu, A. B., Ghosh, B. S., Chakrabarti, S. K. and Ghosh, B. L. (1993). Improvement in properties of jute fibre by treatment with polysaccharide-degrading enzymes. Indian Journal of Text Fibre Research, 18, 101-103.

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Crossref: https://doi.org/10.18801/jstei.110121.75

[17]. La Rosa, A. D. and Grammatikos, S. A. (2019). Comparative Life Cycle Assessment of Cotton and Other Natural Fibers for Textile Applications. Fibers, 7(12), 101. https://doi.org/10.3390/fib7120101
[18]. Morrison, W. H., Archibald, D. D., Sharma, H. M. M. and Akin, D. E. (2000). Chemical and physical characterization of water and dew retted flax fibres. Industrial Crops and Products, 12, 39-46. https://doi.org/10.1016/S0926-6690(99)00044-8
[19]. Van der Westhuisen, M. M. (2018). Preliminary retting research on different kenaf cultivars. South African Journal of Plant and Soil 34, 1-3. https://doi.org/10.1080/02571862.2018.1536931

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Vancouver
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