MORPHOLOGY AND PROPERTIES JUTE FIBERS

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https://doi.org/10.5281/zenodo.7342781

Abstract. *Among all bast fibers, jute is one of the most significant and versatile fibers of commercial and technical importance. Jute, also a cellulosic fiber, ranks next to cotton in terms of production. Jute is an annual herbaceous plant mainly cultivated in the equatorial, the tropical and the sub-tropical zones. Jute plays a vital socio-economic role in producing countries. About 12 million farming families, mainly in South East Asia, are dependent on this crop. Out of over 30 important species belonging to the genus Corchorus, only two – C. capsularis commonly known as 'White jute' and C. olitorius known as 'Tossa jute' – are utilized for fiber production on a commercial scale. This chapter discusses almost the whole gamut of jute starting from its origin, history, agro-climatic condition and production area, economic importance, botanical description, different stages of cultivation, fiber extraction, fiber quality and grading, fiber morphology, structure, chemical composition, properties, products, traditional/unconventional uses, etc. In addition, the chapter briefly describes the environmental advantages and the socioeconomic impacts of jute along with its future potential.*

Keywords*: jute, cellulosic fiber, morphology, structure, genus Corchorus, C. capsularis, C. olitorius environmental advantages, socio-economic impact.*

МОРФОЛОГИЯ И СВОЙСТВА ДЖУТОВОГО ВОЛОКНА

Аннотация*. Среди всех лубяных волокон джут является одним из наиболее значимых и универсальных волокон, имеющих хозяйственное и техническое значение. Джут, также целлюлозное волокно, занимает второе место после хлопка по объему производства. Джут – однолетнее травянистое растение, культивируемое в основном в экваториальной, тропической и субтропической зонах. Джут играет жизненно важную социально-экономическую роль в странах-производителях. Около 12 миллионов фермерских семей, в основном в Юго-Восточной Азии, зависят от этой культуры. Из более чем 30 важных видов, принадлежащих к роду Corchorus, только два — C. capsularis, широко известный как «белый джут», и C. olitorius, известный как «джут Тосса», — используются для производства волокна в промышленных масштабах. В этой главе обсуждается почти вся гамма джута, начиная с его происхождения, истории, агроклиматических условий и района производства, экономического значения, ботанического описания, различных стадий выращивания, экстракции волокна, качества и сортировки волокна, морфологии волокна, структуры, химического состава. , свойства, продукты, традиционное/нетрадиционное использование и т. д. Кроме того, в главе кратко описаны экологические преимущества и социально-экономическое воздействие джута, а также его будущий потенциал.*

Ключевые слова*: джут, целлюлозное волокно, морфология, структура, род Corchorus, C. capsularis, C. olitorius экологические преимущества, социально-экономическое воздействие.*

INTRODUCTION

Among the natural fibers, jute ranks next to cotton in terms of production. Jute is a cellulosic fiber under the category of bast fibers and its cultivation is almost as old as human civilization. Jute, an annual herbaceous plant, is mainly cultivated in South and South East Asia. Jute was first used as an industrial raw material for making packaging materials, replacing flax and hemp grown in Europe [1-5].

When the jute plants were recognized as a source of fiber and utilized for making ropes and sacking, mainly in the Indian subcontinent, is not known definitely [6-9]. References to sacking bags made of jute have been traced to the literary works of the region as far back as 1575. Sackcloth made of jute has been referred to as an article of trade in several Bengali poetical works of the sixteenth and seventeenth centuries. Rumphius in 1743, one of the earliest workers on Bengal plants, gave an illustrated account of jute plants along with a figure of *C.capsularis* mentioning therein that it was under cultivation in Bengal (India), the Arakans and South China. He even mentioned that the fine white thread made out of this fiber was stronger than that from cotton. Jute is believed to have been traditionally in use in many other parts of Asia and Africa since ancient times to provide cordage and weaving fibers from the stem and vegetables of the leaves [10-25].

Although there are several types of jute plant which yield fiber, only two species are cultivable types and the others are mostly wild types, bushy and dwarf. Jute is an annual plant belonging to the genus *Corchorus* of the family Tiliaceae, and also belongs to the sub-order Malvineae of the order Malvales. The number of *Corchorus* species is probably around 50–60, however, over 170 *Corchorus* names are given in the Index Kewensis. The genus is extremely variable, but all species are apparently highly fibrous.

JUTE FIBER MORPHOLOGY

Jute fiber, unlike cotton, is a multicellular fiber. In the jute plant the fiber is formed as a cylindrical sheath made up of single fibers (ultimate cell) joined together in such a way as to form a three-dimensional network from top to bottom of the stem. The commercial fibers, in the form of fiber bundles of 1.5–3 m long, called *reed*, are held together as a unit by the mesh or network structure of the fibre elements and represents only a very small proportion (4–6%) of the whole plant.

Each fiber element of these meshes of a raw jute reed is basically a group of *ultimate cells*, cemented together laterally and longitudinally by means of inter-cellular materials being chiefly non-cellulosic in composition. A single fiber of jute thus comprises a bundle of ultimate. Thus, jute fiber is multicellular.

The ultimate cells are spindle-shaped and of variable size in length and width, being on average 2.5 mm long and 0.02 mm width at the middle. The cells are some 200 times longer than their breadth.

The cross-sections of the ultimate cells are found to be polygonal with rounded corners. The layer of natural gum present between the ultimate cells is known as the *middle lamella*. Each ultimate cell has thick cell wall and *lumen*, the central canal, with a more or less oval cross-section (Fig. 1).

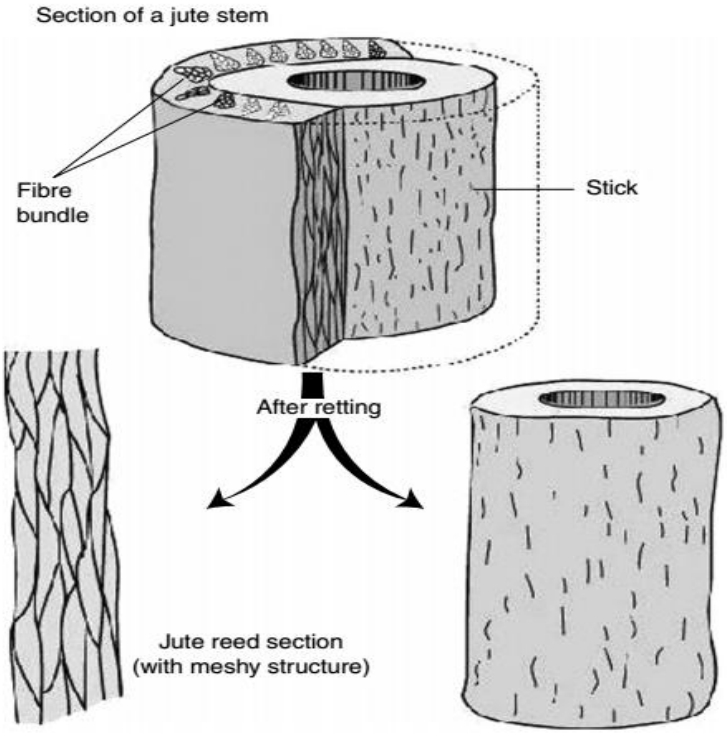

Fig. 1. Disintegration of a jute stem into a jute reed and a stick after retting.

The cell wall of each ultimate cell is composed of an outer thin *primary wall* and an inner thick *secondary wall*, differing from each other in the molecular architecture. Both these walls of a jute ultimate cell are composed of ultra-fine *microfibrils* (Fig. 2).

While in the primary wall the fibrils lie in a crisscross manner, the fibrils are arranged almost parallel as right-hand spirals in the secondary wall. The fibrils in the jute cell wall are arranged in a right-handed spiral with angle of orientation of 7–9° in reference to the cell axis.

Within the ultimate cells of a jute fiber, the ultrafine fibrils, being purely cellulosic, are the highly ordered regions, while the inter-fibrillar regions are less ordered regions which can make room for the presence of short chain hemicellulose molecules to a larger extent and the bulky lignin molecules to a smaller extent as the bonding material of the middle lamella, providing strong lateral adhesion between the ultimate.

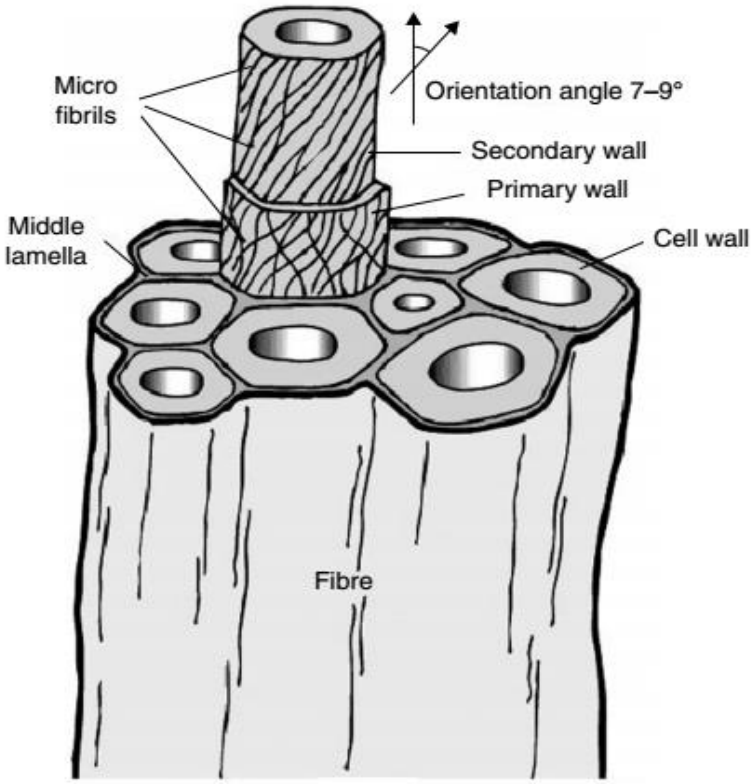

Fig. 2. Jute fiber morphology: microstructure.

PROPERTIES OF JUTE

Commercial jute ranges from pale cream to golden yellow and from light brown to dirty grey in color. It possesses a natural silky shine. Jute is a relatively coarse, stiff, inelastic and somewhat rigid fiber that has slightly higher moisture regains (12–13%) than cotton (7–8%). Good frictional property, tenacity, very high modulus and low breaking elongation make jute an ideal packaging material.

The use of jute is limited to coarse fabrics, because the length/diameter ratio of jute filaments is only 100–120, which is much below the minimum of 1000 required for fine spinning quality. Jute fiber is hygroscopic and wetted filaments may swell up to 23% in diameter.

Other than being of agro-origin (and hence renewable) and biodegradable (and hence environmentally friendly), the major advantageous features of jute are its high strength and initial modulus, moderate moisture regain, good dyeability using different dyes, good heat and sound insulation properties and low cost. However, the major disadvantages of jute are its coarseness, stiffness, low wet strength, moderate wash shrinkage, harsh feel, hairiness and high fiber shedding, photo-yellowing, and poor crease recovery.

Physical properties

Like other bast fibers, jute is a strong fiber with very low extensibility due to its '*composite-like*' structure with highly oriented long chain molecules. The jute fiber shows very poor extensibility, the breaking elongation ranging between 1.0% and 1.8%. Tossa jute is found to be stronger than White jute. Tenacity-wise, the jute filament is comparable with steel. The flexural and torsional rigidities of jute fiber are quite high as compared to cotton or wool due to its coarseness and inelastic structure. For this, jute textile material develops wrinkles and creases easily.

Thermal properties Heating at very high temperature, jute fiber chars and burns without melting. With increasing heat, the chain molecules vibrate more increasingly and ultimately disintegrate leading to violent chemical reactions observed as fiber combustion. With a high specific heat value as of 1.36 × 103 J/kg/K the jute fiber shows good thermal insulation. The ignition temperature of jute, about 193°C, is not high and may be one of the reasons making jute susceptible to catching fire. Like all cellulosic fibers, jute also loses strength on prolonged exposure to sunlight. Jute loses strength at more than twice the rate for cotton.

Electrical properties Dry jute exhibits high electrical resistance but in moist jute, the electrical resistance drops by about 10 000 times. Such variation of electrical resistance with moisture led to the development of an electronic moisture meter. The dielectric constant of jute at a frequency of 2 kHz is 1.8 in the dry state, 2.4 at 65% relative humidity (RH) and 3.6 at 100% RH.

Optical properties The color of jute fibers varies widely from pale creams/yellow to dark brown. In general, the Tossa variety tends to have a reddish tinge while the color of White jute varies from pale yellow to yellow. Good quality jute shows excellent luster. Jute fibers with good molecular orientation show good amount of birefringence, +0.041, the difference between the refractive index along the fiber axis and that perpendicular to it, due to high orientation of chain molecules.

CONCLUSIONS

A few success stories illustrate that jute, the golden fiber, could make a comeback. For example, a jute mill in Bangladesh recently reduced its losses by developing and introducing linoleum fabric, which is being used as an industrial material. Some manufacturing units of India are profitably making attractive bags and diversified jute products including shopping bags. It is perceived that demand for home textiles, particle board, jute-based composites, technical textiles, etc., is increasing. People around the world are becoming more conscious about the pollution caused by synthetics and are increasingly opting for natural fiber products.

It is evident that worldwide use of more traditional jute products and new, alternative and non-traditional items together with the diversified jute products would certainly rejuvenate the jute sector and would reduce pollution to a great extent. It is likely that development of the diversified sector would provide more employment opportunities and alleviate poverty.

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