STRUCTURE AND PHYSICAL-CHEMICAL PROPERTIES OF JUTE FIBERS

Parpiyev H.
Namangan Textile Industry Institute, Candidate of technical sciences
E-mail: parhabib@gmail.com

Gafurov A.
Namangan Textile Industry Institute, PhD student
E-mail: adhamjongafurov1991@gamil.com

Izatillaev M.
Namangan Textile Industry Institute, PhD student
E-mail: muzaffarxon11011994@gmail.com

Abstract:
Among all bast fibres, jute is one of the most significant and versatile fibres of commercial and technical importance. Jute, also a cellulosic fibre, ranks next to cotton in terms of production. Jute is an annual herbaceous plant mainly cultivated in the equatorial, tropical and 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, fibre extraction, fibre quality and grading, fibre 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, genus Corchorus, C. capsularis, C. olitorius, cellulosic fibre, morphology, structure, environmental advantages, socio-economic impact.

Introduction

Among the natural fibres, 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.

Origin. Corchorus species are found in warm regions throughout the world, in all continents and in numerous tropical and sub-tropical regions. Corchorus is a pan-tropical genus comprising an uncertain number of species, with estimates ranging from 40 to 100. However, the center of diversity and origin of the genus appears to be Africa, where the largest number of Corchorus species (around 30) has been found with the highest concentration reported from East and South Africa. Of the cultivated species C. capsularis is omnipresent in Indo-Myanmar and South China, from where it migrated to India and Bangladesh. The primary center of origin of C. olitorius is probably Africa, while India or the Indo-Myanmar region is a secondary center. Both species are cultivated and naturalized in many parts of the tropics, including South East Asia.

History. 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. 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.

Adaptation/agro-climatic conditions. Favorable conditions for jute cultivation are found in the floodplains of the great rivers of the tropics and sub-tropics – the Ganges, the Irrawaddy, the Amazon and the Yangtze – where irrigation, often characterized by extensive flooding, and alluvial soils combine with long day lengths. The crop traditionally thrives very well under rain and hot humid and sub-tropical conditions in the Bengal Basin in India and Bangladesh where more than 80% of the world crop is grown. Jute is mainly grown between 16°N and 27°N, during the hot wet summer season in a hot and humid climate with temperature in the range of 24°C–37°C. Growth is retarded at temperatures below 17°C and above 42°C. The annual rainfall should be 1000–2000 mm of pre-monsoon showers at sowing time.

Areas of production. Jute is mainly cultivated in the equatorial, the tropical and the sub-tropical zones. It is extensively cultivated in India and Bangladesh. Other major jute growing countries are Myanmar, Nepal, China, Vietnam, Thailand and Brazil.
Jute is an annual herbaceous dicotyledonous plant that grows to a height of 1.5–4.5 m (Fig.1). The stems are about 1–2 cm in diameter with few branches. The colour of the stem, petiole,

leaf and pod varies in different forms. Jute fiber is obtained from the bast or phloem layer of the stem. The two species differ in the quality of fiber they yield. Fibers of C. olitorius are frequently softer, stronger and more lustrous than those of C. capsularis.

Figure 1. A view of a jute field.

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 meshy or network structure of the fiber elements and represents only a very small proportion (4–6%) of the whole plant.

Macrostructure. 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 ultimates. 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.2).

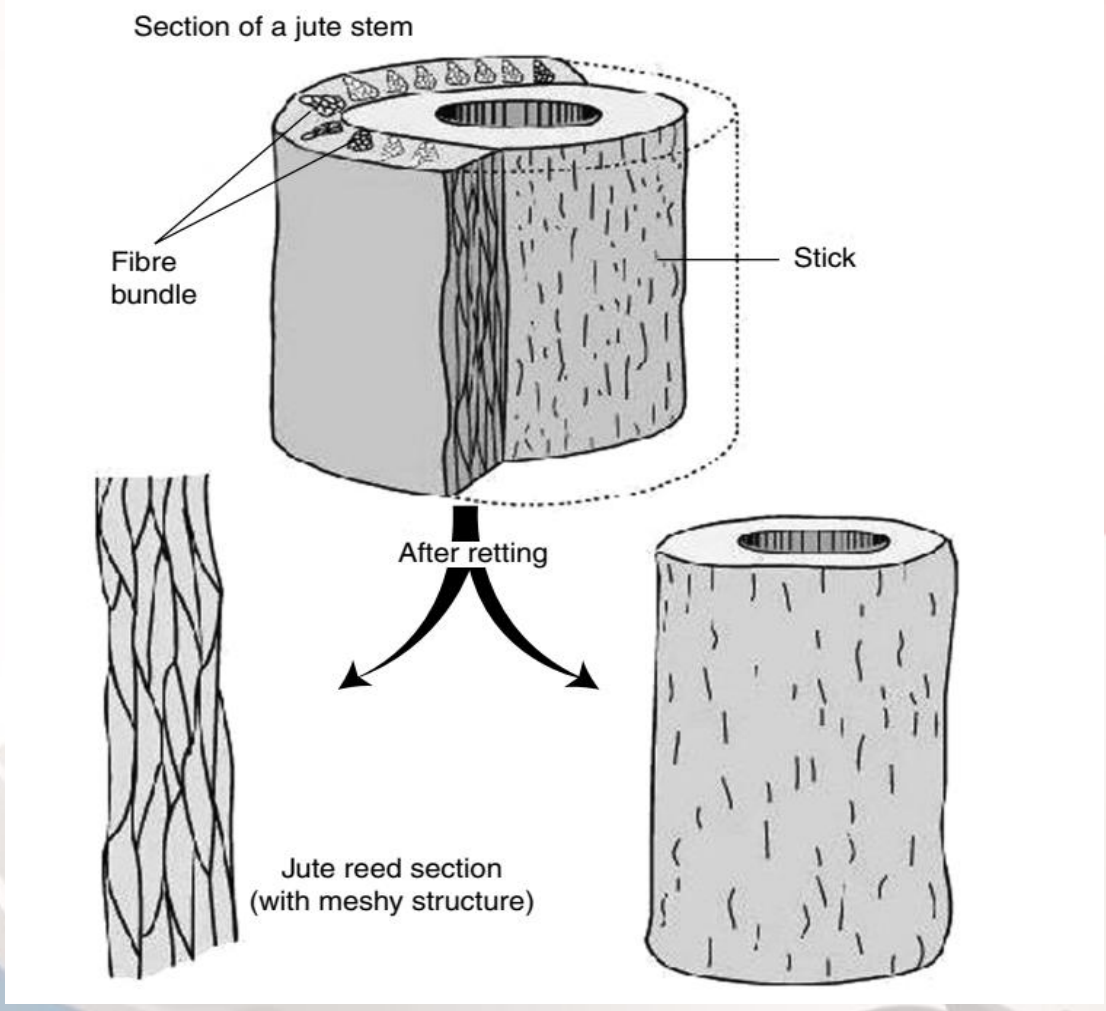

Figure 2. Disintegration of a jute stem into a jute reed and a stick after retting.

Microstructure and appearance. 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. 3). While in the primary wall the fibrils lie in a criss-cross 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 ultimates.

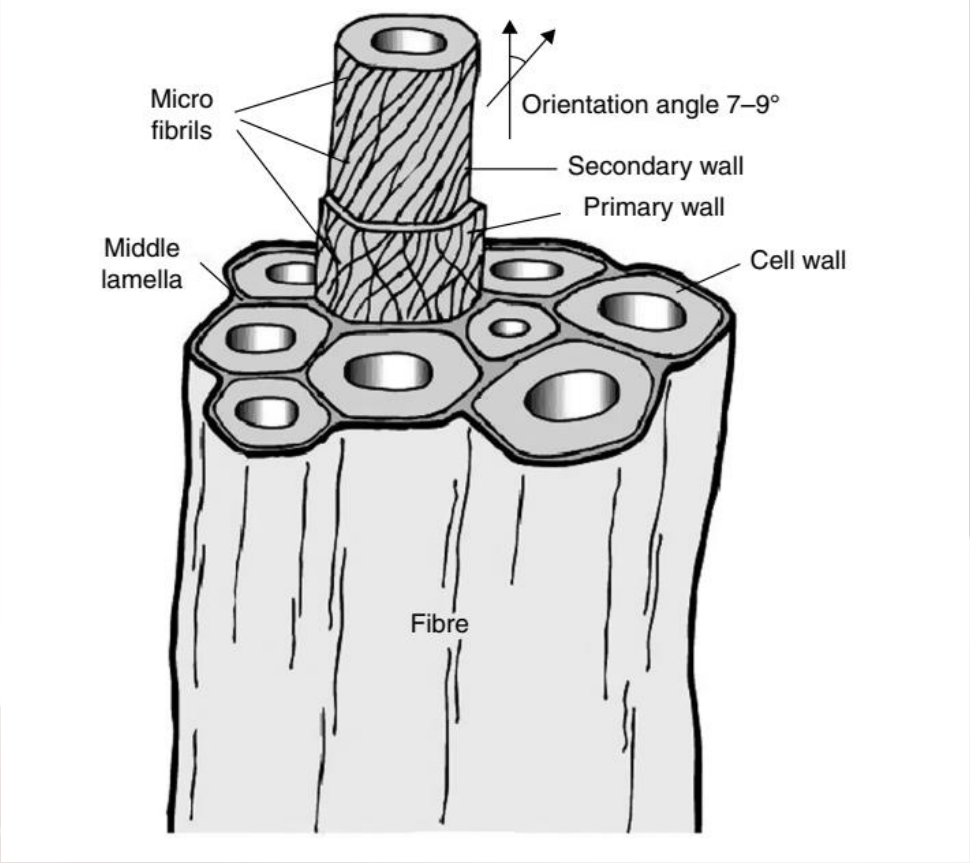

Figure 3. Jute fiber morphology: microstructure.

Chemical composition

The major aspects related to the chemistry of jute and its composition have been described below. Jute fiber is basically a compound of lignocellulose. It is a complex of organic molecules, which on combustion leaves a little ash consisting of calcium, magnesium, aluminium, iron, etc., that are present either in the free state or bonded with functional groups of cellulosic chain. The number of ultimate cells in one such bundle constituting a single fiber range from a minimum of 8–9 to a maximum of 20–25. This wide variation in the number of cells in a bundle is believed to be a major cause of variation in the physical and mechanical properties of the fiber and its quality. The spinnable units in jute fiber strands are, like those in most other bast fiber crops, filaments composed of a string of cells bonded together by pectin and hemicelluloses.

Chemical structure. Chemically, jute fiber is mainly composed of polysaccharides and lignin. The fiber also contains smaller amounts of chemical compounds such as fats and waxes, pectin, nitrogenous, coloring and inorganic matters. The polysaccharides are also called carbohydrates (or holocellulose), and are divided into two groups: alpha cellulose and hemicellulose.

Structure of alpha cellulose. Alpha cellulose is the major constituent of jute. It forms the skeletal structure of jute fiber and belongs to the family of the compounds of carbohydrates. It

contains 44.4% carbon, 6.2% hydrogen and 49.4% oxygen. Its molecular formula is expressed as $(C_6H_{10}O_6)_n$. The chemical structure of alpha cellulose is shown in Fig. 4.

Alpha cellulose is a natural polymer of the poly-condensation kind consisting of D-anhydro glucopyranose units linked together in the chain molecule by 1, 4 β-glycosidic bonds. The alpha cellulose is a long chain polymer. The degree of polymerization (DP) of an alpha cellulose chain is about 10 000 if we consider the 'glucose unit' as the monomer or about 5000 if the 'cellobiose unit' is considered to be the monomer.

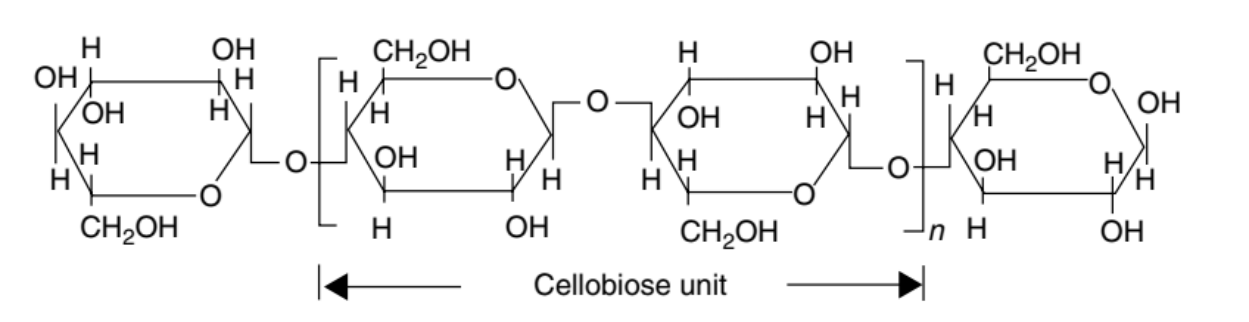

Figure 4. Chemical structure of alpha cellulose.

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.

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.

References

1. Dempsey, J. M. (1975), Fiber Crops. Gainesville, FL: University Press of Florida.
2. Frank, R. R. (ed.) (2005), Bast and Other Plant Fibers. Woodhead Publishing in Textiles. London: CRC Press.
3. Ghosh, P. (2004), Fiber Science and Technology. New Delhi: Tata McGraw-Hill Publishing.
4. Roy, S. (2010), Jute Basics. Dhaka, Bangladesh: International Jute Study Group (IJSG).
5. Sur, D. (2005), Understanding Jute Yarn. Kolkata, India: Anindita Sur.