

VARIATION IN LIGNO-CELLULOSIC PROPERTIES OF JUTE FIBER AND STICK BASED ON PLANT POSITION

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ABSTRACT

This study investigated the ligno-cellulosic properties of jute fiber and jute stick, focusing on variations along different plant sections (bottom, middle, and top). Results for jute fiber indicated that cellulose content was highest at the top (64.57%) and lowest at the bottom (63.18%), while lignin showed the opposite trend, being highest at the bottom (16.07%) and lowest at the top (15.27%). Hemi-cellulose, ash, fat/oil, moisture, and other components in jute fiber did not exhibit significant variations across sections. Similarly, jute stick displayed higher cellulose at the top (47.87%) and lower cellulose at the bottom (46.98%), with lignin following the inverse pattern (25.27% at bottom, 23.91% at top). Hemi-cellulose, ash, fat/oil, moisture, and others in jute stick also showed no significant differences among sections. A comparative analysis revealed that jute fiber contained significantly higher cellulose (~63-64%) and lower lignin (~15-16%) than jute stick (~46-47% cellulose; ~24-25% lignin). Conversely, jute stick had a higher hemi-cellulose content (~25-26%) compared to jute fiber (~18%). These findings highlight distinct compositional profiles between jute fiber and jute stick, as well as gradients along the plant length, which are crucial for optimizing their utilization in various industrial applications, including textiles, paper, bio-energy, and composite materials.

Key words: Jute, cellulose, lignin, plant position.

Introduction

Jute (*Corchorus* spp.) is one of the most important natural bast fibers widely cultivated in South Asia, particularly in Bangladesh and India, for its versatile industrial applications in textiles, packaging, composites, and eco-friendly products. The quality and functional properties of jute fibers are largely determined by their ligno-cellulosic composition, primarily comprising cellulose, hemi-cellulose, and lignin. Cellulose contributes to the strength and flexibility of the fiber, while lignin adds rigidity but can negatively impact fiber softness and processing efficiency (Meshram and Palit, 2013). Several studies have indicated that the chemical composition of plant-based fibers can vary significantly with plant maturity, harvesting time, and the position of the fiber along the plant stem (Kabir *et al.*, 2012; Ramesh, 2016). However, comprehensive information on the positional variation of ligno-cellulosic properties within the jute plant, particularly differentiating between fiber and stick at various stem heights, remains limited. Understanding this positional variation is essential to optimize harvesting strategies and improve the utilization of specific plant sections for targeted industrial purposes. The present study aims to evaluate the variation in cellulose, hemi-cellulose, lignin, and other minor constituents in jute fiber and stick collected from different stem positions (bottom, middle, and top).

Materials and Methods

Jute (*Corchorus olitorius* L.) were cultivated at Jute Research Regional Station, Jagir, Manikganj with proper agronomic management where tossa jute variety 'BJRI Tossa pat 8 (Robi-1)' was used as experimental material. Crop was harvested at a commercially optimal maturity stage. Each harvested plant stem was meticulously sectioned into three anatomically defined portions: the bottom section (basal part), the middle section (central stem), and the top section (apical part). These sections were chosen to represent distinct developmental and structural zones of the plant stem. For instance, the average height of jute plants

can range from 2 m to 3.5 m, with stalk diameters from 2 cm to 3 cm. In one study, the average length of jute stem was 315 cm, with girths of 8.4 cm at the bottom, 7.6 cm in the middle, and 3.4 cm at the top. Following sectioning, the bast fiber (outer layer) and the woody stick (inner core) components were carefully separated from each respective stem section. This separation is critical as the fiber and stick have distinct compositions and applications. All separated samples were then prepared for chemical analysis, typically involving air-drying to a constant weight to remove excess moisture, followed by grinding into a fine, homogeneous powder to ensure consistent sample representation for laboratory analysis.

Chemical Composition Analysis: The chemical composition of the jute fiber and stick samples was determined following established and widely accepted standard methods to ensure reproducibility and comparability with other studies. Cellulose, hemi-cellulose, lignin, ash, fat, moisture and other minor compounds of both jute fiber and stick were measured by standard protocol of TAPPI method according to BJRI (2024-2025).

Statistical Analysis: The data were statistically analyzed using Analysis of Variance (ANOVA) to compare ligno-cellulosic properties across different plant positions (bottom, middle, top). Differences among treatment means were adjusted by Duncan’s Multiple Range Test with the help of a computer based statistical package program MSTAT-C (Gomez and Gomez, 1984).

Results

Cellulose content of jute fiber and stick varied significantly among different position of jute plant. The top section of jute fiber showed the highest cellulose content (64.57%), which was statistically identical with middle section and the lowest amount of cellulose content was found in bottom section of jute plant; as shown in Table 1. Similar to fiber, the highest cellulose content was measured in top section (47.87%) and the lowest amount of cellulose was measured in bottom section (46.98%) in jute plant which was statistically different and cellulose content of middle section remains in middle position (Table 2).

Table 1. Ligno-cellulosic properties of jute fiber

Treatment	Cellulose	Hemi-cellulose	Lignin	Ash	Fat/Oil	Moisture	Others
	(%)						
Bottom	63.18b	18.67a	16.07a	0.94a	0.41a	10.45a	0.73a
Middle	63.94a	18.35a	15.64ab	0.88a	0.44a	9.97a	0.75a
Top	64.57a	18.15a	15.27b	0.85a	0.47a	9.68a	0.69a
CV	0.54	1.56	1.52	6.45	11.36	6.69	10.41
LSD (0.05)	0.6910	0.5737	0.4746	0.1148	0.0999	1.3414	0.1504

Table 2. Ligno-cellulosic properties of jute stick

Treatment	Cellulose	Hemi-cellulose	Lignin	Ash	Fat/Oil	Moisture	Others
	(%)						
Bottom	46.98b	25.32a	25.27a	0.82a	0.34a	9.47a	1.27a
Middle	47.38ab	25.66a	24.64ab	0.79a	0.35a	9.21a	1.18a
Top	47.87a	26.02a	23.91b	0.76a	0.37a	8.92a	1.07a
CV	0.80	1.90	1.69	6.03	10.46	4.54	8.78
LSD (0.05)	0.7569	0.9730	0.8321	0.0951	0.0739	0.8346	0.3538

Hemi-cellulose, ash, fat/oil, moisture and other components found statistically non-significant both jute fiber and stick (Tables 1-2). Lignin content was varied significantly among different position of jute plant both fiber and stick. The highest amount of lignin was measured in bottom section of jute plant both fiber and stick(16.07% and 25.27%, respectively) and the lowest lignin content was measured in top section of jute plant both fiber and stick(15.27% and 23.91%, respectively) (Tables 1-2).Results revealed that,

cellulose with lignin, cellulose with hemi-cellulose, cellulose with moisture, lignin with fat, lignin with fat, fat with hemi-cellulose, fat with moisture were negatively correlated each other and on the other hand hemi-cellulose with lignin, hemi-cellulose with moisture, lignin with moisture, hemi-cellulose with ash, lignin with ash, moisture with ash, cellulose with fat were positively correlated both fiber and stick of jute plant (Table 3).

Table 3. Correlation co-efficient between lignocellulosic compounds of jute fiber and stick

	Cellulose	Hemi-cellulose	Lignin	Ash	Fat/Oil	Moisture	Others
Cellulose	1.000000	-0.996920	-0.999943	-0.990742	0.998545	-0.996169	-0.612943
Hemi-cellulose	-0.996920	1.000000	0.996026	0.998337	-0.991241	0.999959	0.549086
Lignin	-0.999943	0.996026	1.000000	0.989237	-0.999064	0.995179	0.621339
Ash	-0.990742	0.998337	0.989237	1.000000	-0.981981	0.998819	0.500000
Fat/Oil	0.998545	-0.991241	-0.999064	-0.981981	1.000000	-0.990004	-0.654654
Moisture	-0.996169	0.999959	0.995179	0.998819	-0.990004	1.000000	0.541494
Others	-0.612943	0.549086	0.621339	0.500000	-0.654654	0.541494	1.000000

Discussion

The data reveal distinct compositional differences between jute fiber and jute stick, as well as variations along the length of the plant for certain components. Jute fiber consistently shows significantly higher cellulose content (average ~63-64%) compared to jute stick (average ~46-47%). This is expected, as cellulose is the primary structural component of plant fibers, contributing to their strength and rigidity (Mohanty *et al.*, 2000). For both jute fiber and jute stick, cellulose content tends to increase from the bottom to the top of the plant. This suggests a gradient in maturity or developmental stage, with the upper sections potentially having more developed cellulose structures. This trend could influence the properties of derived materials, with fibers or sticks from the top potentially offering higher strength due to increased cellulose crystallinity (Yang *et al.*, 2007). The higher cellulose content in jute fiber makes it desirable for textile and pulp industries.

Jute stick generally contains a higher percentage of hemi-cellulose (average ~25-26%) than jute fiber (average ~18%). Hemi-cellulose, being a branched polysaccharide, contributes to the cell wall structure and acts as a binding agent (Rowell *et al.*, 2005). The higher hemi-cellulose in jute stick might contribute to its more rigid, woody nature compared to the pliable fiber. Jute stick exhibits a considerably higher lignin content (average ~24-25%) than jute fiber (average ~15-16%). Lignin is a complex polymer that provides rigidity and waterproofing to plant cell walls, and its higher concentration in jute stick is consistent with its role as the woody core of the plant (Boerjan *et al.*, 2003). Conversely, lignin content shows a decreasing trend from the bottom to the top for both jute fiber and jute stick. This is often observed in plant growth, where the lower, older sections of the stem tend to be more lignified for structural support, while newer growth at the top might have less lignin (Sjostrom, 1993). The lower lignin content in the top sections could be beneficial for processing, requiring less harsh chemical treatments for delignification. The lower lignin content in jute fiber is advantageous for various applications, as lignin removal is an energy-intensive process in pulping and textile processing.

The observed variations in ligno-cellulosic composition along the jute plant highlight the importance of considering the source (fiber vs. stick, and location within the plant) when utilizing jute biomass for different applications. The high cellulose and lower lignin content of jute fiber make it an excellent candidate for textile, paper, and cellulose-based material production. The slight increase in cellulose and decrease in lignin towards the top of the fiber could indicate that top sections are marginally superior for these applications. Jute stick, with its higher lignin and hemi-cellulose content, is more suited for bio-

energy production (e.g., bio-ethanol, biogas), production of bio-chemicals, or as a raw material for particleboards and composites where lignin acts as a natural binder (Islam *et al.*, 2017). The variations in lignin and cellulose along the stick could influence the efficiency of conversion processes.

Conclusion

Cellulose, hemi-cellulose and lignin are the most important lignocellulosic component of jute plant. Results revealed that, cellulose and lignin content varied significantly and were negatively correlated among different plant position both fiber and stick of jute plant.

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