Coconut Fibre: Properties and Applications

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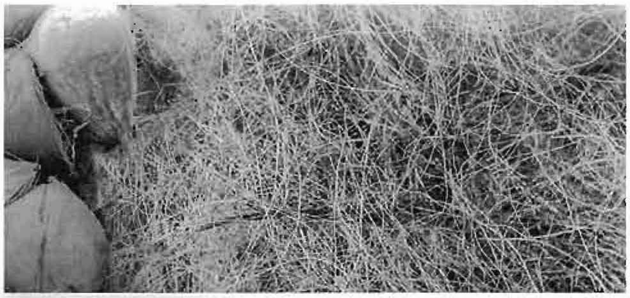
Introduction

Coconut fibre made from coconut husks is a valuable industrial material predominantly produced in tropical coastal regions like India, Sri Lanka, and the Philippines. India and Sri Lanka lead global production. Recently, India has increased production of coconut fibre due to rising demand for eco-friendly materials. However, traditional extraction methods like water retting raise environmental and health concerns, leading to a decline in India's yarn production and affecting exports. To address this,new automated and eco-friendly fibre and yarn extraction methods are needed to improve fibre extraction efficiency and to reduce the drudgery associated with it.

Husk and Fibre

The coconut husk consists of the inner endocarp and outer mesocarp, containing fibres and elastic cells. Retting separates the tough, lignified cellulose-rich outer cover from the fibrous mesocarp. Coconut pith, the husk's non-fibrous cells, contributes significantly to its weight. Fibre quality and quantity vary widely among 300 coconut eco-types, and mixing fibres from different types reduces quality and increases variability. The best fibres come from nearly ripe to ripe nuts and are categorized into coarse, medium, and fine groups. Mixing these groups results in lower-value and rougher products. To create higher-quality products, fibre should be sorted and cleaned into three grades. Sorted by fineness and length, coconut fibres are used for mattresses, textiles, brushes, and brooms. They can also be sorted by color, either white or brown. However, no established standards exist for strength, moisture content, non-fibrous material presence, and flexibility, which are crucial for commercial use. Additionally, no machine currently available can accurately separate fibres by grade. Coconut



fibres, attached to the mesoderm with pectinous matter, can be removed by hand or machinery after softening the husk. Traditionally, coconuts are harvested 12 months after growth for copra, leading to tough, brown fibres, often considered secondary and overlooked for quality. Retting is best with fresh husks, separated soon after harvesting, as exposure to sunlight or prolonged storage reduces fibre quality. The traditional retting method in salty backwater lagoons is cost-effective, where green husks from 10-11 month-old nuts are submerged for 6-10 months. This produces whiter, softer fibres compared to artificial water retting. Retting involves two stages: physical swelling of the husk and biological breakdown by microorganisms, which separate the fibres. After retting, husks are beaten by hand to loosen fibres and remove the outer layer. Fresh husks yield fibres ideal for bleaching and dyeing. Mature brown husks involve soaking, dehusking with sharp shovels, disintegration, washing, and defibreing with machines. The sun-dried fibres are used in brushes, doormats, mattresses, sacks, rubberized coir, automobile upholstery, and geotextiles. This process is inefficient, requiring excessive machinery and power. The quality and quantity of coconut fibre depend on factors such as husk age, coconut variety, season, local conditions, and retting yard location. Typically, husks make up 35% of the coconut's weight, with fibres ranging from 30% to 50%, yielding 10% to 17.5% of the coconut's weight in fibre. For example, in Sri Lanka, 1000 husks yield about 140 kg of fibre, while in India, the yield is around 90 kg. This includes bristle fibre, mattress fibre, and other qualities.

Yarn manufacturing

Coconut fibre yarn production is largely handled by households and co-operatives, accounting for over 75% of the total output. In Southern India, particularly Kerala, traditional manual spinning wheels called 'ratts' are used, requiring at least three people to produce 12-15 kilograms of yarn daily. Efforts to motorize these wheels aim to reduce labor, but issues with productivity and yarn quality persist. A new spinning machine developed for the purpose is reported to increase productivity to 50 kg/h with one operator, using a synthetic core covered with coconut fibres. However, this machine produces coarser, fuzzier yarn mainly for ropes, lacks safety features, and offers limited twist options. Bleaching, using hydrogen peroxide and sodium silicate, enhances the brightness of coconut fibre products like mats and carpets. Treatments with fungi or bacteria, such as *Trametes versicolor*, improve fibre softness and brightness without losing strength. Dyeing is another technique used in fibre industry to improve the visual appeal of coir products, which was traditionally done by heating large vessels with fuel wood, adding dyestuff and chemicals, and maintaining specific temperatures and fibre-to-liquor ratios. Upgraded dyeing technologies now use stainless steel tanks with electric heaters. Post-dyeing, the yarn is washed and dried in the shade.

Properties of coconut fibre

An average coconut fibre has length (8-337 mm, mostly 15-145 mm), fineness (27.94 tex), density (1.15 g/cm^3 raw), deformation (11% permanent), moisture regain (8-12.5%), and swelling behaviour (15-34% transverse, minimal longitudinal). Compared to jute, coconut fibres are longer, wider, less dense, with lower tensile strength but higher work of rupture. They contain more cellulose, less lignin, and have lower crystallinity (25-33%). Composed of 49.6% carbon and 6.1% hydrogen, coconut fibres resist water, alkalis, and acids. Microscopically, they show uneven surfaces due to wax or fat, which clean with alkali treatment. Thermal analysis indicates lignin breakdown around 280°C. Spectroscopy confirms the presence of cellulose, lignin, and hemicelluloses.

Chemical Treatments in Coconut Fibre

Alkali treatments, particularly with NaOH, significantly impact coconut fibres, causing weight loss and darkening. A 10% NaOH treatment results in a 12.65% weight loss and produces finer fibres, with larger diameter fibres experiencing more size reduction. While alkali treatment can weaken fibre strength by disrupting certain bonds, it can also improve tensile properties and increase fibre tenacity by enhancing cellulose purity and crystallinity. The treatment removes cements holding fibrils together, increasing elongation at break. FTIR and thermal analyses indicate hemicellulose removal and cellulose breakdown at higher alkali concentrations. Acid treatments, such as hydrochloric and acetic acid, also cause weight loss but with less color change. Oxidizing treatments effectively remove waxy substances, while combinations of treatments (e.g., NaOCl followed by hydrogen peroxide) can further enhance fibre properties. Various other treatments, including UV radiation, ethylene dimethacrylate grafting and chemical modifications like dinitrophenylation and diazo coupling, can significantly improve mechanical properties and reduce moisture absorption. These treatments modify surface morphology, increase sorption, and enhance interfacial bonding in composites. For wood fibres, a combination of Na_2S, Na_2CO_3, and NaOH proves most effective for chemical softening without causing breakage. This mixture decreases flexural rigidity and increases the length/diameter ratio of wood fibres, with Na_2S acting as a reducing agent to slow down cellulose degradation in the alkaline environment.

Uses of coconut fibre

Treated coir products which are lighter and more rigid, are replacing traditional coconut fibre items, finding use in pillows, carpets, and erosion prevention. High-twisted twines are used to create geotextiles with significant tensile strength, aiding in erosion control and water retention. Synthetic matrix composites incorporating coconut fibre are being explored, which has the potential to reduce stiffness and production costs. Coconut husk is a promising bioenergy source, with potential applications in

ethanol production. Similarly, nanoscale cellulose whiskers derived from coconut fibres exhibit thermal stability and efficient dye adsorption properties. Coconut husk particles have been found effective in removing dyes and heavy metals from wastewater.

Conclusion

Coconut fibre varies in size, with a low length-to-width ratio. Longer fibres are better for spinning, while shorter ones suit composites. Despite modest strength, it excels in elongation and energy absorption. Its structure, with comparable lignin and cellulose content, resists microbes and maintains moderate moisture gain. High rigidity limits fine yarn production, favoring coarser textiles. To optimize use, mechanized spinning and efficient supply chains are needed. Coconut fibres are ideal for compressed mats in various applications. Future focus should be on improving fibre quality, positioning coconuts as fibre crops. ■

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