Machinery for extraction and traditional spinning of plant fibres

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Vegetable fibres are produced from bast, fruit, seed, leaf, and sheath of plants. They are discrete of single entities as in cotton; ligno-cellulosic meshy as in jute and mesta; long as in jute, mesta, flax, sisal, ramie, pineapple leaf fibre (PALF); and short as in areca nut, kapok. Some of them like cotton and ramie are strong and fine with high length to breadth aspect ratio for good spinability into yarn for fabric. Primarily, cotton is used for apparel; jute and mesta for packaging; ramie for fabrics, ropes and currency paper blanks; sisal for rope; flax for linen; sun hemp for rope and tissue paper, etc. Ramie is the strongest amongst all the vegetable fibres and, therefore, it has great promises for specialised applications. The traditional uses of some vegetable fibres are in packaging of food grains, sugar, potato, onion, etc. Emphasis has, therefore, been given to crops like jute, mesta, sisal and PALF right from their extraction to finished products like yarns, fabric, sacking, hessian, ropes, twines, soil-savers, craft papers, etc. through mechanical processing and intervention of a host of machinery. The need for production of fine yarn/blended yarn has become acute in the context of manufacture/export of fabrics and ready-made garments. Therefore, it becomes essential to explore all spinning technologies for production of market friendly yarn.

Keywords: Plant fibre, Traditional spinning

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Unlike plastics, vegetable fibres are biodegradable, annually renewable, non-carcinogenic and therefore health-friendly. Traditionally, jute and jute-like mesta are being used for packaging as sacking, hessian, bags and soil savers besides being used as carpet backing, jute scrim, tarps, canvas, tar felts, etc. There are other diversified uses too as technical textiles, geotextiles, agro-textiles and handicrafts. Other allied vegetable fibres like ramie, sisal, flax, pineapple leaf fibre, coir, etc. are also used in single form or in union with jute. The agronomical factors that contribute to good quality jute fibre are close spacing of crops, reduced nitrogenous fertilizers, intercropping and multiple cropping, application of Azotobacter inoculants to soil, pre-flowering harvesting and canal retting1. Post-production retting and mechanical processing which are the two next most important factors specific to the crop are covered. Microbial activity in aqueous medium helps in eliminating pectinous gums and lignin that bind the fibres. The retting process varies from crop to crop and the same is covered in brief under each crop. All the plant fibres mentioned here are natural cellulosic and multicellular in nature except cotton which is unicellular. The major constituents of all cellulosic fibres are α-cellulose, pentosan and lignin. High α-Cellulose and low lignin content of a fibre are necessary for its textile application. The chemical composition of the vegetable fibres are also reported (Table 1)2.

Jute

The two cultivated varieties are Corchorus capsularis & Corchorus olitorius belonging to Tiliaceae; locally called pat, nalita, marapata, patua & jhot. Capsularis is usually called tita pat & guti pat and olitorius called mitha pat, tossa & daisee3. Jute has a mesh structure with reed length of about 1.5-4.5 m and each fibre element of a raw reed, available commercially, is found to be an overlapping group of about 5-15 cells, the ultimate cells, cemented together laterally and longitudinally by means of inter-cellular materials chiefly of non-cellulosic composition and hence jute fibre is multicellular. The jute ultimates are 2.5 mm long on an average, approximately 18 microns wide at the middle and taper towards each end. The average linear density of single jute filament usually lies between 1.3-4.0 tex for tossa jute4.
The two cultivated mesta varieties are Hibiscus cannabinus & H ibiscus sabdariffa, belonging to Malvaceae. Cannabis is called kenaf while sabdariffa is roselle. Mesta is inferior and coarser than jute, yet it is a substitute of jute contributing 7% by kenaf & 5% by roselle to jute production, respectively. Andhra Pradesh is the home of kenaf.

Methods of harvesting of stalks and preparation of fibre (retting, stripping, beating etc.) are similar to those of jute. The fibre is used in the manufacture of fishing nets, coarse canvas sacks, twines for tying rafters, floor matting, etc. The continued research has opened up the scope of using mesta pulp as an excellent substitute for bamboo.

Cotton

Cotton is a natural fibre of vegetable origin like linen, jute or hemp. Mostly composed of cellulose (a carbohydrate plant substance) and formed by twisted, ribbon-like shaped fibres, cotton is the fruit of a shrubby plant commonly referred to as the cotton plant. The cotton plant, Gossypium sp (Malvaceae), which comprises approximately 1,500 species, also including the baobab tree, the bombax or the mallow. Either herbaceous or ligneous, it thrives in dry tropical and subtropical areas. Whereas by nature the plant is a perennial tree (lasting about 10 yrs), under extensive cultivation it is mostly grown as an annual shrub. The cotton fibre (Gossypium hirsutum) (0.1-0.3 tex) is finer than jute fibre (1.3-4.0 tex). Cotton is a single fibre entity having an average length of 25-50 mm. The major end uses for cotton fibre include wearing apparel, home furnishings, and other industrial uses (such as medical supplies).

Ramie

Ramie (Boehmeria nivea) is a semi-perennial hardy shrub which yields the strongest vegetable fibre. It grows to a height of 1.5-2.5m and 12-18 mm in diameter. The leaves which grow at the upper part are heart shaped. It requires a warm humid climate for good vegetative growth. It cannot tolerate water-logging and severe winter. Decortication is done immediately after harvest which frees the fibre in the form of fibre strands by removing the bark and woody part of the stalk. With the highest aspect ratio of 3,500, ramie as a bast fibre stands strong so far as its spinability is considered. This is long like jute but not meshy, yet ramie has no established spinning system like jute and cotton. From 22% level, gum content needs to be reduced to less than 6% level by boiling to make ramie spinable.

Flax

Linum usitatissimum Linn. (Linaceae) known as flax or linseed fibre and locally as alashi, atasi, etc. is extracted from the stalks of lenum and harvested when the capsules are immature. Linseed oil and flax fibres are different varieties while some varieties excel in both. Flax is relatively non-lignified, soft, flexible, lustrous and pale yellow. Its fibre is superior to jute for spinning as its 25-50 mm long fibres are free of meshwork. Flax spinning is not different from jute spinning system although it does not require breaker-carding. Flax may, however, be spun on cotton system, if properly blended with cotton.

Sisal

Sisal (Agave Sisalana) is a multicellular leaf fibre with very short ultimates (0.5-6 mm) but long as a
bundle with tenacity of 40-45 g/tex, which is higher than jute (30-50 g/tex)\(^2,3\). The fibre foremost among the hard fibres is long, bold, creamy white and exceptionally strong. Sisal grows well on a dry permeable sandy loam and is exceedingly drought resistant. The leaves are cut for fibre between the third and fourth year. Each plant yields about 250-300 leaves during its life-time of 7-8 yrs. Sisal leaf is decorticated mechanically to extract fibres which are washed in plain water and sun-dried. It has no established spinning system; rather the fibres are twisted into rope. The fibre is eminently suited for cordage of all kinds. It has the ability to carry loads and can, therefore, be attractive as the reinforcement.

**Pineapple leaf fibre**

Pineapple leaf fibre is obtained from the *Aananas cosmosus* (Bromeliaceae) leaves and the plant is biannual and perennial having rather short life\(^3\). The leaves of the plant are 1-1.60 m long, 5-7.5 cm width tapering to a point like sword shaped. The leaves are dark green in colour freshly in appearance and are flat with spiny edges. The leaves of the pineapple produce a strong, white, fine and silky fibre. The yield of the fibre is approximately 2.5-3.5% of the weight of the fresh green leaves. Fibre has aspect ratio (450) 4 times higher than jute and bundle tenacity as good as sisal. Leaf is decorticated like sisal on rasp bar to extract fibres from pulp, washed and sun-dried. Pineapple fibre has no separate spinning system of its own and is, therefore, twisted instead into rope. There is a possibility of blended product from cotton-pineapple leaf fibre in cotton machinery using below 50% of fibre in the composition\(^6\).

**Banana**

The stem of the banana plant is usually thrown away once the plantain is harvested. The stem forms a major waste material in large-scale banana plantations. And for the large-scale farmers, the disposal of these stems is a real problem. Fiber can be extracted from banana stem both manually and by mechanical extractor. A wide range of products including bags, baskets, wall hangings, floor mats, home furnishings, etc. can be made with banana fibre. The fibre extracted by mechanical process is of superior quality and is extensively used for making high quality special paper and decorative papers. Banana fiber is used to manufacture handicrafts, home decorative, door mats, table mats, pooja and meditation mats. In some countries, banana fiber used for making of currency paper. Banana fiber is being used in making socks in European countries\(^7\).

**Coir**

Ripe and dried coconut husk produce coir fibres which are short in length (ultimate cell length 0.5-4 mm) and coarse. Coconut husk is kept submerged in water up to 6 months and then bitten to loosen coir. It is very coarse with very low aspect ratio and is, therefore, not suitable for spinning. Coir fibres are twisted into rope. Spinning into yarn from coir is not possible; however the practice of alkali boil in soda makes the fibres somewhat soft to be blended with jute for manufacturing yarn of medium to higher poundage. As such, coir has, therefore, no spinning system for making single yarn of its own. Hence, rope is the only technically feasible product from the coir fibres. There are also possibilities of using waste fibre as fillers in cement, latex and other industrial adhesives\(^3\).

**Machinery to extract fibres**

**Jute**

Traditionally, defoliated long plant stems are jucked in submerged water in small bundles up to 20 days or 3 weeks. Alternatively, only the ribbons of green stem are retted in comparatively low water and for fewer days. In the third method, ribbons are chemically treated to accelerate retting. The NIRJAF ribboners are both manual (Fig. 1) and power operated (Fig. 2), which peel out the green ribbon like green barks from the defoliated stem by keeping the woody stick intact\(^8\). In manual ribboning, simple country devices could be improvised for stripping the green barks from single plant. For this, a vertical pole, bamboo hooks and bicycle hub can well be used for extracting the green ribbon by manual operation. The capacity of a manual ribboner is 150 kg of green ribbon while that of power unit is 1,500 kg/day. The power ribboner developed by NIRJAF peels off the green barks in the form of ribbons by compression in pairs of rollers. The CRRIJAF power decorticator strikes the stems by rotating blades and removes the green ribbon by breaking the stick into pieces, while the manual one produces whole stick (Fig 3)\(^9\).

**Cotton**

After bolls of cotton are picked by hand or by mechanical picker-harvester from matured plants, they are ginned with the help of either saw or roller gins to separate the 15-60 mm discrete fibres from
lints. Plant debris and foreign matters are removed by cleaner from ginned cotton, and the clean cotton characteristically of good spinability with aspect ratio of 1,300 is processed through a series of machines in the entire spinning lines like opening & cleaning in blow-room, carding, drawing, roving and spinning to manufacture yarn as fine as 120⁰ Ne to as coarse as 20⁰ Ne³

**Pineapple leaf fibre**

The pineapple leaf fibre (PALF) can be obtained from green leaves by peeling and scrubbing; by scrapping followed by retting in water and by mechanical decortication. A handy mechanical scratcher is run by paddle operation for disintegration of impervious layer on the leaf surface. The power operated (Fig. 4) uses rotary cylinder mounted with rasp bars to scratch out green matter thus turning out 1,500 kg of green fibre per day.¹⁰ Some of the machinery developed for sisal decortication can also decorticate pineapple leaves by making appropriate adjustments.

**Sisal**

The raspador decorticator of 1.20 m in diameter and 225 mm in width has been scaled down with modifications (Fig. 5) followed by 5 hp design with capacity of 60-75 kg of green fibre. Washing the fibre is done by repeatedly dipping the hanks in a series of concrete tanks filled with water.

**Banana fibre**

A low cost, user-friendly device for extracting fibres from the pseudostem of banana has been developed. It can extract 15-20 kg fibres from the banana wastes in a day as compared to 500 gm a day through the laborious manual process. The machine consists of a rigid frame on which the roller rotates. The roller is made of horizontal bars with blunt edges, and it is driven by a one hp single-phase electric motor. For feeding the banana pseudostems, adjustable guiding rollers are provided. The machine reduces the drudgery, and provides a clean working environment for the labourers. It increases the fibre production (Fig. 6) by fifty times.⁷ The machine-extracted fibre is of superior quality in terms of length, softness, strength and colour.

**Flax**

Retted and sun dried flax is scutched to break the woody stick into pieces and thus separate the fibre reed in a scutching machine (Fig. 7).¹¹ As a first step, butting is done to make the root ends of the wide and cured bundles of straw even. The shive is broken and removed from the fibre bundles with a minimum of fibre waste, leaving the bundles clean and undamaged. Besides, there is a host of other machinery developed for fibre extraction, but all operate on essentially the same principle i.e. straw passes between fluted rollers which break shive in a great many places through out its length.

**Coir**

Coir dehusking machine is used to separate the husk from the coir fibres. The husks are removed and put through a machine composed of a pair of corrugated iron rollers. These rollers are known as breakers which crush them. These semi-opened coir fibre is further fed to the coir extractor (Fig. 8) for thorough opening and cleaning of coir fibres. The longer and stronger ones are washed, cleaned and dried. There are other methods of extraction of coir fibre by decorticating dry husks. All the processes yield basically three types of fibre depending on the methods of extraction viz. mat fibre (longest fibre), bristle fibre and mattress fibre.

**Processing of plant fibres**

Spinning systems of different plant fibres are shown (Fig. 13). Jute, *mesta* and sun hemp can be processed in jute system because of their near similarity in fibre structure and physico-mechanical properties. Jute being a coarse fibre compared to cotton, the processing machinery starting from fibre to fabric formation is mechanical, much robust and heavy duty. Cotton as a finer fibre requires very mild and intensive opening than jute. Due to mesh like structure, jute fibre unlike cotton requires a very high amount (shear strength < breaking strength) of opening force to de-mesh or split the jute reeds. It has been found that the average jute fibre length in the yarn stage is around 200 mm.⁴ Because of this higher staple length of jute fibre in comparison to cotton, the roller settings in the yarn processing machinery (drawing to spinning) are wider than those of the cotton yarn spinning machinery. Thus the machinery for cotton spinning system is not suitable for jute spinning system and vice versa. However, the flax (2.5-6 tex) and ramie (0.4-0.8 tex) which are also bast fibres having discrete filament structure much finer than jute (1.3-4 tex) but coarser than cotton (0.1-0.3 tex) can be processed in flax system.
Fig. 13 Process flow chart of some plant fibres.
(different from jute system). In the present scenario, the cost of ramie and flax is much higher and therefore they have limited usage in garments rather than in packaging. On the other hand, pineapple (2.5-6 tex) is much finer than sisal (16-35 tex). At present, sisal fibre is popular as ropes and scrubbers. The commercial use of pineapple in India is unknown. Because of its low L/B ratio (95) and high rigidity (150-250 dyn.cm$^2$), coir is not spinnable but pliable into rope (coir system). It cannot, therefore, be processed on jute, flax or cotton systems. In contrast, PALF has been tried successfully on jute, cotton, flax and semi-worsted spinning systems. Besides, the other systems for fibre processing like wool, worsted and silk (as animal fibres) are not suitable for the processing of most plant fibres and hence out of the context. The traditional spinning systems and the relevant engineering properties corresponding to each spinning system are mentioned (Table 2). The process flowcharts of some plant fibres are also shown for better understanding.

**Cotton system**

The series of standard machines required to process coarse cotton are bale openers, carding, drawing, speed frame, spinning frames (Fig.9), winding machines for spun yarn followed by assembly winding and plying machine for ply yarn. Further, these yarns are processed through series of weaving preparatory and weaving loom machines to give the final shape of woven fabric. After harvesting and drying, the cotton balls are fed to cotton ginning unit to separate fibre from the seeds. The compressed cotton in the form of bale is opened in the blow room using a series of machinery, usually 3-5 depending on the trash or foreign particles embedded in the cotton. Then the carding process is initiated where fibre to fibre separation and further cleaning take place. The output of carding in the form of sliver is fed to drawing frame and roving frame for gradual improvement of fineness of the fibre mass prior to spinning. Spinning produces coarse yarn known as carded yarn. For fine yarn spinning, additional process of combing is used which yields combed yarn.

**Flax System**

Flax in India is primarily used for oil and not for fibre; however, it has a good potential for sacks used for packaging. As flax fibres are long single entities, their machineries are somewhat different from jute machinery. The machinery for flax are hackling, carding, drawing, and spinning for yarn preparation (Fig. 10).

**Jute system**

Prior to mid 1850s, raw jute was being used for hand made ropes. As a matter of fact, jute processing followed wool and flax since 1850s and continued till 1970s in roving system and then sliver replaced round roving prior to spinning. Later on full scale spinning system was developed. They comprised of softener, both breaker and finisher cards, drawing and roving frames and spinning, plying, winding frames in order to obtain yarn (Fig. 11). To prepare fabrics in weaving machine, warping, sizing and weaving machines are needed. Half a dozen of industries are engaged in making these series of machines in the country. Retted jute reeds are harsh and are bound together. The mechanical processing of jute depends largely on its physico-mechanical properties (Table 3).

**Coir System**

Coir being very coarse and harsh is extensively used in villages for weaving mat of cots. Basically, they are also used for tying bamboo and wooden rafts in homes, scaffolding and temporary structures. Therefore, the machines in processing coir into ropes are coconut dehusker, beater for retted coir, coir opener, coir drawing (for sliver preparation) and rope spinning-cum-winding machine (Fig. 12).

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<th>System of spinning</th>
<th>Engineering properties</th>
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<td>Fineness, tex</td>
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<td>Flax</td>
<td>2.5-6</td>
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<td>Cotton</td>
<td>0.1-0.3</td>
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<td>Jute</td>
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<td>Coir</td>
<td>25-40</td>
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<td>Wool</td>
<td>0.7874-2.76</td>
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<td>Worsted</td>
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Conclusion
Among all these fibres spinning system for plant fibres, cotton is the oldest followed by flax, jute and coir system. The finer fibre like cotton requires more number of machineries for conversion of fibre to yarn compared to coarse fibre like jute, banana, sisal, flax, etc.

References
1 Kundu BC, Basak KC & Sarcar PB, Jute in India, (Indian Central Jute Committee, Calcutta), 1959, 98-105.
2 Anonymous, 50 Years of Research 1939-89, (Jute Technological Research Laboratories, Indian Council of Agricultural Research, Calcutta), 1990, 75-77.
6 Pandey SN, Pineapple Leaf Fibres, (Indian Council of Agricultural Research, New Delhi), 2005, 29-44.
7 Sudhakar R, Venkatasubramanian V, Deo Singh K & Srinivas I, Banana fibre extractor—a need based user friendly invention, (Krishi Vigyan Kendra, Central Tobacco Research Institute, Rajamundry, Andhra Pradesh), 2003.