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Bast and leaf fibres: A comprehensive review

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Abstract
Since 21st century, the 'green' consumption of world has been continuously rising. This has resulted in green fibres and the eco-textiles being seen as the developing trend of the textile industry. The new environmental plant fibres have lot of scope for development. There is a need to save non-renewable energy and adequately employ the existing natural resources. This leads to exploration of various unconventional sources for developing new plant fibres. This paper reviews various bast and leaf fibres which are being utilized in textile applications and research is still going on to improve them further for high-end applications. An attempt has been made to compile various aspects related to fibre extraction, properties and their end applications.

Keywords: bast fibres, jute, flax, hemp, PALF

Introduction
Growing consciousness of the world's limits of dwindling fossil fuels and raw materials has made us question the first phase of industrial manufacture that saw materials as cheap and endlessly renewable and fashion as primary stimulant to demand. The future of textiles lies in the development of new fibres and fabrics. Recent advancements have been quiet innovative where aesthetics is as important as performance. Today textile companies are very much aware of potentially harmful effects to the environment and due to this, they work with in strict guidelines with ecology often being a main concern. The needs, both of the consumer and the environment are being more closely considered with textiles being developed from renewable sources and manufactured with minimum impact on the environment [1]. Famous designers and popular fashion brands are going green by using eco-friendly fibres in the manufacture of clothing and other apparel.

Stringent environmental regulations and consumer awareness are driving the transition to a bio-based economy and sustainable development which offer wide scope for natural fibre markets. Shifting to a bio-based economy requires substitution of many common raw materials that are presently being produced from fossil (petrochemical) or mineral resources largely, with products produced from renewable resources [2].

Natural fibres play a key role in the emerging "green" economy which focuses on concern for the environment, the well-being of fibre producers and consumers, and the conditions of workers in the textile industry. They are carbon neutral: they absorb the same amount of carbon dioxide they produce. During processing, they generate mainly organic wastes and leave residues that can be used to generate electricity or to make ecological housing material. And, at the end of their life cycle, they are 100% biodegradable. Year 2009 was the International Year of Natural Fibres with an aim of raising global awareness of the importance of natural fibres not only to producers, industry and consumers but also to promote the efficiency and sustainability of industries based on natural fibres.

Almost all natural fibres are produced by agriculture, and the major part is harvested in the developing world. Globally some 30 million tonnes of natural fibres are produced annually; largely by countries that are economically backward. In many developing countries, proceeds from the sale and export of natural fibres contribute significantly to the income and the food security of poor farmers and thus is of major economic importance [3].

Natural cellulosic fibres are from various parts of the plants. The fibres are mainly classified as seed fibres (e.g., from cotton and kapok), stem or bast fibres (e.g., from flax, jute, hemp, Kenaf, and sugarcane), and leaf fibres (e.g., from pineapple, banana). These fibres may be from plants grown primarily for the fibres (e.g., cotton, flax, hemp, kenaf, etc.) or from plants

in which the fibres are primarily considered a by product coconut (the fibres are often referred to as "coir"), sugarcane, banana, and pineapple. The by product- type fibres have not been used extensively for several reasons including limited availability, difficulty in extraction, lesser lesser performance-related properties, and limited growing regions [4].

Bast fibres are removed from plant material by retting. The cell walls of soft, bast or true fibres are cellulose and are not easily broken down by bacteria. In retting, the plant material is placed in water or kept wet, while anaerobic bacteria digest away most of the plant tissue except the fibres [5].

Hemp, flax, jute, kenaf and ramie plants are all producers of bast fibres, which mean that the fibre is predominantly located beneath the bark of the plant stalk, otherwise known as the phloem [6]. The fibres are found within the inner bark of the stem/stalk of the plant and in the woody core. This structure in turn, necessitates a different way of extracting and processing the fibres. Bast fibres often have fibres that demonstrate varied properties and are located in the very centre core of the stalk. Bast fibres are a natural and renewable resource that can be used in textile products, but, just as with any natural material, there is a variance found from crop to crop. The mechanical properties of bast fibres are influenced by the variety grown, the growth and weather conditions, the date of harvest, the degree of ripeness at harvest, and the retting procedure as well as the decortication, processing, and cleaning processes [7].

Some of the major bast fibres are discussed below

Jute

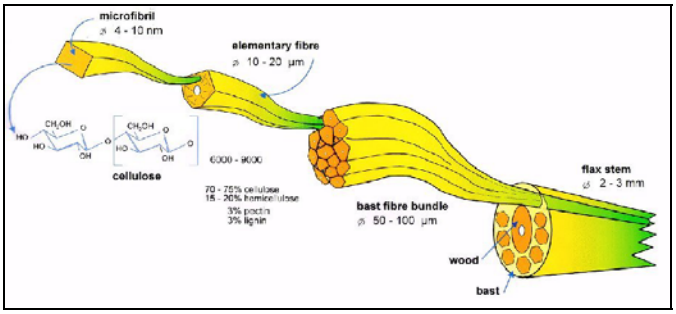
Jute is a natural fibre with golden and silky shine because of which also called as the golden fibre**.** It is one of the cheapest vegetable fibres obtained from the bast or skin of plant's stem. The jute fibre is the second most important vegetable fibre after cotton, as far as usage, global consumption, production, and availability is concerned [8]. Jute is mainly extracted from the stem of white jute plant (*Corchorus capsularis*) and from tossa jute (*C. olitorius*) in lesser quantities. It is a very difficult crop to grow and harvest [9]. India and Bangladesh are the primary producers of the jute fibres in world, responsible for 93% of total world production. Bangladesh is the world's largest exporter of jute [10]. Due to jute's biodegradable nature, it is used to make containers for planting young trees and geo-textiles for soil erosion control where application is designed in such a manner, that it breaks down after sometime and no removal is required. Jute fibre is widely used for making yarn and twine, hessian, carpet backing cloth and as well as for other textile blends. The finest jute fibres can be used to make imitation silk. Jute is also blended with wool. Jute is treated with caustic soda to improve its crimp, softness, pliability, appearance and enhance its ability so that it could be spun with wool. The fibres are used for weaving curtains, chair coverings, carpets and area rugs. Jute fibre is extensively used in sacking for agriculture goods, rigid packaging material and reinforced plastic. It is also replacing wood in pulp and paper industry [2]. Figure 1 shows some of the articles made of jute fibres.

As awareness for eco-friendly materials from sustainable resources is gaining momentum, jute sector is regaining its market both in traditional and diversified applications. However, for making jute products eco-compliant and to increase cost competitiveness of jute commodity items, continuous efforts are being made to develop effective, eco-friendly and cleaner processing technologies. Roy & Basu (2009) developed products like school and laptop bags using specially engineered yarns which comprised of core spun jute yarn wrapped with polypropylene multifilament and concluded that jute fibres could be a better substitute for synthetic fibres used to manufacture such products [11].

Fig 1: Different articles made of jute fibres

Flax

Flax fibre is stronger, crisper and stiffer to handle as compared to cotton. It has a tendency to absorb and release water quickly which makes linen comfortable to wear in hot weather.



(**Source:** www.agrofibrecomposites.com)

Fig 2: Flax fibre structure

In India, linseed/flax is cultivated exclusively for seed and oil out of which, 20-25% varieties yield good quality flax fibre. Figure 2 shows internal structure of the flax fibre from arrangement of fibre bundles in stem to elementary fibres to micro fibrils. All these different fibre forms are quite different as far as their mechanical properties are concerned. Flax fibre bundles are being obtained from the stem through breaking and scutching. These fibre bundles are often used in natural fibre mat reinforced thermoplastic (NMT) and thermo set composites at commercial scale. The lateral strength of fibre bundles is poor as compared to their axial strength, which may be due to the weak pectin bonds between the fibres. Elementary fibres are the strongest having an average tensile strength of up to 1500 MPa [12]. Flax fibre is produced in Madhya Pradesh, Uttar Pradesh, Bihar, Chhattisgarh, Jharkhand, Orissa and some other states. India does not hold a significant place amongst the flax fibre producing countries. India is importing flax fibre to meet demand for flax from the defence sector. China, France, Belgium, Belarus and Ukraine are the major flax fibre producing countries. About 70% of the total flax produced is used in the textile industry. Lower fibre grades are also used as reinforcement and filler in thermoplastic composites. Coarse flax fibres are used for manufacture of strong ropes, shipping cord, twines, kitchen towels, sails, tents and canvas. Fine grade flax fibre is used for manufacturing of good quality suiting-shirting fabrics, cloth laces and household textiles [13].

Hemp

Hemp fibres are obtained from the stem of the plant. Hemp is primarily cultivated only in some districts in Uttarakhand, Kashmir and Kerala. Presently, India does not hold strong position in the map of hemp producing countries. The cultivation of hemp is limited to selected parts of the country, primarily due to requirement of low temperature of soil at the time of planting. Hemp fibre is a good conductor of heat. It has affinity for dyes, resistance to mildew, protects from ultra violet rays (UV) and has natural anti-bacterial properties. Hemp is used for making rope, canvas and paper. It is woven to make linen-like fabric which can be used in clothing, home furnishing textiles and floor covers. It is also used as reinforcement in moulded thermoplastics in the automobile industry and composites for insulation are being made using hemp fibres. There is an increasing awareness about hemp fibre and a wide range of hemp products are now available in the market, made from different parts of the plant. France, Germany, China are among the major producers. Some countries have restricted production of hemp, as it is confused with marijuana.

Ramie

Ramie is one of the strongest natural fibres. It is a white colour fibre with silky lustre, has low elasticity and good dye uptake. India has many varieties of ramie and is found across a number of north- eastern states, Uttarakhand and Himachal Pradesh while it is commercially produced only in some parts of Assam, North Bengal and Maharashtra. China is the biggest producer of ramie fibre while Brazil and Philippines come next to it. The price of ramie fibre is on an increasing trend as it has become popular while its supply is limited in international markets. China, Brazil, the Lao PDR and the Philippines grow ramie plant mainly for obtaining fibres. The yarn produced from ramie fibre can be used for a wide range of garments. It is generally blended with other textile fibres. It is also suitable for making twine, rope and nets [14].

Kenaf

Kenaf is a crop which has a long history of being used since ancient times. It was considered as an alternative crop and the products made from it were simple and cheap. It is believed that kenaf was earlier used in Northern Africa and production of kenaf is being practised in India for over 200 years. In the United States, research for using kenaf began during World War II when there was an increased demand for cordage material during war. The production of kenaf in United States on a commercial scale began in the early 1940s because jute fibre imports were disrupted due to World War II [15]. Kenaf has been cultivated in Egypt since around 4000 B.C. China is also one of the largest kenaf producers in the world [16]. Kenaf fibres are coarse, brittle, and not uniform due to which they are hard to process using conventional textile or non woven fabric equipments [17]. The major producers of kenaf at present are India, Bangladesh and China [18]. Recently use of kenaf for a high end use has been identified i.e. kenaf could be blended with cotton for making fabric and yarn. The fabrics made from the blended yarn seem aesthetically pleasing and soft to the touch. The lightweight kenaf blended fabric resembles linen in appearance [19]. Retted Kenaf has also been found suitable to be used for numerous applications like furniture, shoes and outerwear because of its natural absorbency and fire-retardant properties [20]. Kenaf is being used as a substitute for wood to produce pulp and paper by some countries [21]. Research has shown that natural fibre/plastic compounds using kenaf, can replace glass-reinforced plastics in many applications, like automotive industry, packaging, and construction/housing industry [22].

Sisal

Sisal industry in India is not an organized one. It is mainly cultivated in arid and semi-arid regions of states like Andhra Pradesh, Bihar, Orissa, Karnataka, Maharashtra and West Bengal. Various government agencies (different states) have promoted the cultivation of sisal in these states. India is the 2nd largest importer and 5th largest exporter of sisal in the world. The cultivation of sisal, fibre extraction and making products of sisal fibre is a labour intensive process, which requires very low level of technology. There are some problems associated with sisal like, long time taken for cultivation, low pace of introduction of new products, insufficient efforts for creating awareness about the fibre and its products. Moreover, the extraction process of sisal fibres has not been changed much over the years. Brazil, China, Tanzania and Kenya are the major producers of sisal in the world. Sisal fibre can be used as a substitute for silk fibre. Sisal fibre has been traditionally used to make twines and ropes. In present scenario, sisal is being used for making specialty paper, in filters, geo-textiles, mattresses, carpets and wall coverings. It is also used to reinforce plastic composite materials and furniture. Use of sisal for different applications varies according to its grade. In addition to textile usages, the by-products from sisal extraction are used in bio-gas, pharmaceutical ingredients and building materials [23].

Nettle

The common stinging Nettle, *Urtica dioica*, is a wild plant that grows very easily on damp ground. It is quite similar to flax and hemp and can be used for producing fine linen like cloth. The first known nettle textile found in Europe is from the late Bronze Age. Though it does not appear to have been used for fibre and textile production as much as flax and hemp fibres were used [24]. The stinging nettle or common nettle is a common perennial weed of Northern Europe. It's disliked because of its unpleasant sting and the difficulty of removing the plant once it is established. Nettle fibres are white, silky, and up to 50 mm long. The fabric produced from them is finer and more silky than flax, hence it is possible that fine linens for the affluent class may have been woven from nettle rather than flax during early times [25]. Countries like England and Germany have been making continuous efforts to establish this fibre since 1999, and also made considerable progress in this direction. Nettle fibre has been proved to be a good replacement for glass fibre as reinforcement fibre for polymer matrix composites. It has an advantage of being lighter and more flexible than glass. It has also been found suitable for composite mats for the interiors of cars and urea formaldehyde-bonded particle board [9].

Banana Fibre

India is the world's largest producer of banana; whereas only 10% of the banana waste (pseudo stems) is used for extraction of fibre and rest is wasted. Abaca fibre, which also belongs to the same family as banana fibre, is being successfully used in Philippines since many decades and hence is also named as, Manila hemp. Philippines is the largest producer of abaca fibre in the world, while it is also produced in Ecuador and other Southeast Asian countries. The other major banana producing countries are China, Brazil, Ecuador and Indonesia. Philippines and Japan are the countries producing banana fibre

for manufacturing of textile items at large scale [14]. Recently India has developed a banana fibre separator machine, which can produce silk grade fibre for use in handicrafts and textile industries. Application of banana fibre for manufacturing textiles is a novel concept as far as India is concerned. Banana fibre gets easily blended with cotton or other synthetic fibres to produce fabrics and textiles. Currently, it is mainly used at cottage level industry in southern India. The fibre has got potential to partially share the consumption of cotton and jute fibre in India. This fibre also finds use in high quality security currency paper, packing cloth for agriculture produce, ships towing ropes, wet drilling cables etc.

Pineapple Leaf Fibre (PALF)

Pineapple leaf fibre which is obtained from pineapple leaves is white, creamy and lustrous as silk while 10 times as coarse as cotton. This fibre can easily retain dyes. Pineapple plants are grown at a large scale in tropical America, in Far-East Asian countries and Africa. India holds the sixth position in producing pineapples in the world. The states that produce pineapple in large quantities are West Bengal, Assam, Karnataka, Bihar, Tripura and Kerala [26]. In India, the manual process employed for extracting pineapple fibre is very laborious. There is a great need for marketing activities which can promote pineapple fabric in India. The pineapple plant is largely used as a source of fibre in Philippines and Taiwan, The major end use of this fibre is for making famous Barong Tagalog, wedding gowns and other traditional costumes of Philippine. Less delicate fabrics are used for hanker-chiefs, table linens, bags and other clothing accessories [27]. It finds varied uses across the various parts of the world. There is huge potential for PALF fabric, because of its diverse uses and eco-friendly properties.

Coir

Coir is a coarse and short fibre which is extracted from the outer shell of coconuts. It is the thickest and most resistant of all commercial natural fibres. Its slow decomposition rate is a major advantage for making durable geo-textiles. The fibre is extracted from the tissues covering the seed of the coconut palm (*Cocos nucifera*), which is grown in the tropical regions. There are two types of coir; coarse brown coir and finer white coir. The more commonly used is brown fibre obtained from mature coconuts while white fibre is extracted from immature green coconuts after soaking for up to 10 months [28]. Coir is a material which is very helpful in overcoming the problem of erosion. It is woven into geo textiles and used in areas that require erosion control. It promotes new vegetation by absorbing water and also prevents top soil from getting dry. Coir geo textiles have a natural tendency to retain moisture and give protection from the harmful radiation of sun which does not happen with geo-synthetic materials. Other benefit of using coir is that it provides good soil support for up to three years which allows natural vegetation to be established. Generally, white coir spun into yarn is used for manufacturing rope. It has strong resistance to salt water which makes it suitable for fishing nets. Brown coir is stronger than white coir. Various applications of coir fibre include sacking, brushes, rugs, mattresses, doormats, packaging material and insulation panels. It is also used in combination with natural rubber for filling up mattresses, automobile seats, settees, sofas and seating systems. Automobile producers in Europe use pads of brown coir bonded with rubber latex for upholstery. Because of its insulation properties, coir finds application in panels, cold storages, food industry, etc. Though coir industry is fully developed only in India and Sri Lanka, but it holds an important position in economy of countries like Brazil, Indonesia, the Philippines and Vietnam. Globally around 650 000 tons of coir are produced annually, out of which India and Sri Lanka have the major share. Around 80 percent of the coir produced in India is exported in the form of raw fibre only while smaller quantities are exported as yarn, mats, matting and rugs [2].

Bamboo Fibre

Natural bamboo fibre is called as original bamboo fibre. Original bamboo fibre is extracted from natural bamboo by using physical and mechanical means without any chemical additives. The production of original bamboo fibre is facilitated by stripping of natural raw bamboo. The bamboo strips are then steamed, crushed and decomposed. Afterwards, degumming is done using enzymes. The natural bamboo fibre obtained is then carded. The fibres have a length of approximately 90 mm which can also be cut in staple length for cotton spinning system or other length according to the end use.100% original bamboo yarn is also possible to spin. However, it could also be blended with other fibres, like, cotton, viscose, modal, milk, polyester, silk etc. Original bamboo fibre retains the characteristics of natural bamboo due to natural production process. It also exhibits excellent functional properties like antibacterial, anti-UV, fast moisture absorption and release. Natural original bamboo fibre can be used for both knitting and weaving [29].

Conclusion

Textile industry uses a wide variety of natural fibres. Besides their use in textile production, natural fibres provide employment opportunities to millions of people which contribute substantially to the economy of many countries. There are many fibre-yielding plants in all the regions of world, which can be economically exploited in an eco-friendly manner. Even marginal exploitation of these fibre-yielding plant resources could prove a milestone and reap significant benefits for the society.

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