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# Characterization and mechanical properties of bast fibre

**Tanushree and Bhawana Chanana**

**Abstract**
So far no detail study has been carried out for scientific extraction of the fibres from any of these plants and the characteristics of fibre have not been evaluated properly. It is envisaged that there will be global shortage of conventional natural fibres by the turn of the century. In this context. The search for new fibre bearing non-conventional plants will be an appropriate step towards meeting the future demand of natural fibre. Hence the present study was undertaken with the general objective to optimize the methods for extraction of Bast fibres from certain non-conventional plants and to evaluate their physio-chemical characteristics.

**Keywords:** Natural fibre, mechanical properties, tensile strength, cellulose, tensile properties, tensile strength, characterization

## Introduction

A complete new machine line for the processing of natural fibre plants has been developed, which includes all process stages from pick-up and cutting of straw bales up to the cleaning of the final products, fibres and shives. Processing of non-retted Bast fibre plants is the particular innovation of this technology. Thereby, stabile fibre qualities are ensured, which meet the quality demands of the utilizing industries. Hemp, flax and Linseed fibres can substitute wood, synthetic, carbon and glass fibres in a wide range of industrial products. The knowledge of the mechanical properties of these fibres is essential for the choice of the best fibres for each individual design and calculation of structural elements, fabrics, heat insulation mats etc. The most important fibre data, such as fineness, diameter, length, strength, modulus of elasticity, elongation and cleanness are presented, which are based on comprehensive measuring results. It has to be considered, however, that in practice the real parameter of the natural fibres vary in a wide range.

These Bast fibres are extracted from the vegetables as vegetable fibres. Considered to be quite strong and flexible with respect extractability from the xylem material from the woods and even from certain vegetables. They are also found in the epidermis layer of some plants. These are reported to occur in the form of bundles that are glued through the pectin and calcium ions {ex- in case of okra *(Abelmoschus esculentus)}*. Due to this they are selected to replace the hard wood fibres and the glass fibres. Mostly preferred to have a high tensile strength and can even be used in high quality textiles, even can be blended with some fabrics like cotton and synthetic ropes to make a proper stuff. As per the researchers, it is said to contain quite special structure like that of the fibre node.

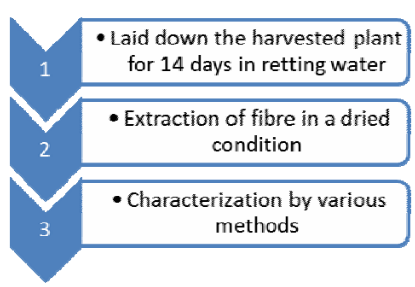


**Fig 1:** A Raw step

**Methods and Materials**

To characterise the Bast fibres obtained from the vegetable or plant source, necessary steps are being followed;-

- The harvested plant product is laid down in the retting water for about 14 days.
- Extractions of the fibres are then done in a shed with a dried condition.
- Characterization of these fibres are then by various methods.

**Characterization process**

This process is sincerely followed to investigate the fitness of the fibres using the gravimetric method. In this process, the tissue fibre obtained is measured diametrically using a scanning electron microscope (SEM). While the tensile strength is measured using a single fibre tensile testing machine. To study the chemical and functional groups present in the fibres, the Fourier transform infrared spectrometer was used that determine the amount of Cellulose, Pectin, Water, Soluble Matter and Hemi- Cellulose present in the fibres.

An X- ray diffraction (XRD) pattern of the fibres were obtained with the X-ray detector to calculate the crystalline nature of the fibre. For measuring the tensile property an electric single fibre tensile apparatus was used with a standardised protocol.

**Mechanical properties of Bast fibres**

These are made from microfibrillar angle which are representing the angles built between the micro fibrils and the longitudinal cell axis inside the cellulosic fibres. These are inversely proportional to the stiffness of the fibres. The microfibrillar angle of Bast fibres is generally lower than that of leaf and seed fibres making the Bast fibres stiffest of all. The Bast fibres are going to provide with a proper and higher tensile as well as flexural strength, leaf finers might also be present for a better performance. It is also reported that due to this kind of stiffness, Bast fibres constitute the most researched fibres in the composite production area. The mechanical properties of some of the agro residual fibres are compared with important Bast from other sources.

The mechanical performance of the plant fibres are affected negatively from higher temperature in the presence of oxygen. These are what insist the researchers to consider the Bast fibres to replace other kind of fibres.

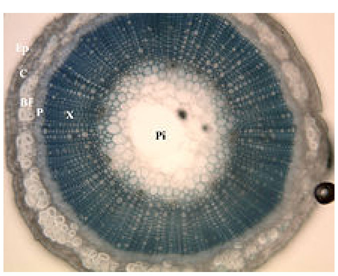


**Fig 2:** An overview

**Termination**

- There was longitudinal view observed showing some of the crack- lines along the length of the fibre, which indicates the fibre clusters held together by some sticky material in it.
- The crosses sectional view showed that the fibre clustered in the groups are an assembly for the Bast fibres, where the clusters of fibre were held together by certain non-fibrous materials.
- This particular set of characterization is done to reveal the percentage of cellulose, lignin, hemi- cellulose, water soluble matter, pectin and wax in the provided fibres.

The chemical composition and the morphological microscopic structure of these vegetable tissues are extremely complex due to their hierarchical organization and the different compounds present at various concentrations. These vegetable and plant fibres are composed of cellulose and non- cellulosic materials as mentioned above, apart from that there are some of the water soluble compounds attached to it. There are lignin and pectin that act as a bonding agent in the particulars.

Reportedly these Bast fibres are produced and are used to manufacture a broad range of traditional as well as certain novel products with addition to that of paper and board materials. These can be used in many ways, for example in the form of fine powder as in case of saw dust, short fibres as in case of random and non- woven mats or even long fibres like that of woven mats for making various kinds of biocomposite products.

Advantages of Bast fibres over the traditional reinforcing fibres like that of glass and carbon include low cost, low density, high toughness, acceptable specific strength properties, improved energy recovery, carbon dioxide sequestration and biodegradability. With the increasing consciousness of preserving the environment and saving the ecosystem, there is a need to recycle; there has been a renewed interest in composite sectors using natural fibres as partial replacement for synthetic carbon, glass or aramid fibres. The long fibres offer a greater flexibility for enhancement processes, particularly in the woven and pultrusion composite industries. Later these long fibres are transformed to threads or yarns that are used to join, connect or attach to each other. As said accordingly, any textile fibre should be made up of long chain molecules, so that it ensures a continuity and strength along the length of the fibre axis. The homogeneity of these long fibres depends very much on the technique of producing the fibre bundles. This is known as the retting of degumming process.

**Common Bast fibres**

Quite a common form of Bast fibre, hemp (*Cannabis sativa*), that developed from the source of plant Bast fibre and has gained a considerable interest for producing a strong and durable fibre. This is hemp that prefers a mild climate, humid atmosphere and a rainfall of at least 625 to 750 mm per year. Hemp mostly prefers good soil moisture for seed germination and for the young plants to grow until about a month old. This predominantly grows in the East and the south East Asian countries.

In a country like India, jute is considered to be one of the common and mostly used Bast fibres. This is traditionally used as textile fibres for the purpose of fabrics, mostly and predominantly used for making jeans and other heavy duty types of fabrics. As being one of the most recommended textile fibres, jute produces quite poorer quality of fabrics as compared to cotton and silk. To improve its quality it is mixed with other kinds of supplementary substituent's like that of pulp and paper products.

Getting back to the ancient era, there is flax; another important form of Bast fibre that is advantageous for being grown and harvested within 3 months of time under a reasonable moisture and relatively cool temperatures. This has been considered as a source of linen, which has being providing a quite high quality fibre for textiles since 1000 long years. It provides fibres that are used in many applications including packaging materials, reinforcements for plastics and concrete, asbestos replacement, panel boards, lining materials for vehicles and even as an alternative for fibreglass as an insulating material.

Most significant advantage of the flax fibre is its ability to absorb nearly 12% of its own weight inside water resulting with increase in its strength by 20%. It also dries quite quickly and is an anti- static. Considering its application, it can be a suitable substituent for man- made synthetic fibres like that of heavier fibreglass. These fibres are two times strong as those of cotton and five times stronger as that of wool. After alkali treatment of jute fabric, oligomeric siloxanetr eatment is conducted to promote adhesion between jute fibre and polyethylene matrix. Mechanical properties of fabricated composites such astensile strength, flexural strength, and interlaminar shear strength (ILSS) were evaluated. The tensile strength is observed to increase from 17.5MPa for untreated jute fabric/LDPE composite to 27.7MPa for oligomeric siloxane-treated alkalized jute fabric/LDPE composite. Provided that jute fabric is treated with alkali and oligomeric siloxane, a 39% increase is observed in the flexural strength.

**Critical analysis for its mechanical properties**

Characteristics that are considered to be the criteria to determine the fibre quality are;-

- Fibre strength
- Cleanliness and fitness
- Color and luster
- Length and percentage of cutting

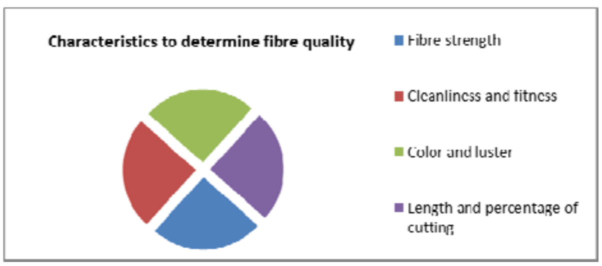


**Fig 3:** Characteristics to determine fibre quality

The complete strength of the fibre is assessed with snapping a few strands by hands, a quite qualitative procedure that gives a useful identification to an experienced operator. Cleanliness and freedom from non- fibrous matter that is an important feature, and in that respect the physical imperfections result from improper retting that can have a profound effect on the allotted grade.

Colour becomes quite irrelevant, but certain end users traditionally prefer particular colours of fibre for the sake of appearance. Lustre is an indication to determine the strength. These properties would determine the success of using the fibres in a fine, woven textile structure.

For the growth of these Bast fibres, a complete favourable cultivation condition would lend better growth of the fibre quality. Some grow in alluvial soil that has shown a better fibre quality that that growing on the sand, comparatively better than the peat soil. For these Bast fibres, the necessary factors are levels of fertility, temperature, plant density and irrigation that could improve the fibre quality.

Bast fibers have been grown for centuries throughout the world. Bast plants are characterized by long, strong fiber bundles that comprise the outer portion of the stalk. Bast plants include flax, hemp, kenaf, sunn-hemp, ramie, and jute. The focus of our research has been on the species that can grow in temperate regions of the world, namely flax, hemp, and kenaf. These fibrous plants have long been noted for their exceptional strength in cordage and paper. The primary focus of our research will be from a North American perspective, although occasional references will be made to applicable international developments.

The word "Bast" refers to the outer portion of the stem of these plants. This stringy, vascular portion comprises 10 - 40% of the mass of the stem depending upon the species of Bast plant, as well as the particular variety, or cultivar, within a Bast plant.

The remainder of the stem inside this Bast layer is a different type of fibrous material, which has different names depending upon the species selected. This inner material is known as shives when referring to flax and sometimes hemp, as heard in the context of hemp, and as core when from kenaf. For the purpose of simplicity and consistency, we will use the word "core" when discussing this portion of the Bast plant. (Ershoves and Kriehevsku, 1975) [9].

Depending on the extraction process, the chemical composition, fibre shape, fibre strength, flexibility, and ability to adhere to other fibres or matrix differ widely between different types of woods. This makes it difficult to predict the mechanical properties of the natural fibre reinforced composites. Joshi *et al* (2004) studied comparative life cycle assessment of natural fibre and glass fibre composites.

Natural fibre is emerging as low cost, light weight and apparently environmentally superior alternatives to glass fibres in composites. Natural fibre composites are likely to been environmentally superior to glass fibre composites in most cases; for instance, the natural fibre production has lower environmental impacts compared to glass fibre production and end of life incineration of natural fibres results in recovered energy and carbon credits. Plant based composites may in future, become materials to replace polymer based composites and wood in terms of their attractive specific properties, lower cost, simple processing technologies, eco friendliness, and ability to be recycled after use reported by Ndazi *et al* (2006). The quality and performance of plant based composites can further be improved by adopting appropriate engineering techniques. Research on natural fibre composite is still relatively new. It is clear that improvements must be made if natural fibres are to compete with synthetic fibres on the composite market.

The adhesion between the fibre and the matrix, the processing of the fibres and the structure of the fibres are examples of areas that need to be studied in more detail. The adhesion between the fibres and the matrix is crucial to all fibre composite materials. If the adhesion is good, stress is transferred between the load carrying fibres over the matrix, which makes the material strong and stiff. The fibre extracted by retting and manual processes has been used to fabricate the composites. These composites were tested for tensile, flexural and dielectric properties and compared with those of established composites like sisal, bamboo and banana made under the same laboratory conditions.

It has been observed that the tensile properties increases with respect to volume fraction of fibre for vakka fibre composite and are also more than those of sisal and banana composites and comparable to those of bamboo composites. The flexural strength of vakka fibre composite is more than that of banana composite and is closer to sisal fibre composite with respect to the volume fraction of fibre, whereas the flexural modulus is much higher than those of banana and sisal fibre composites and also very much closer to bamboo fibre composites.

Influence of fibre morphology of different natural fibres on the composites mechanical properties and on the fibre breakage due to extrusion process.
The composite materials were manufactured using long fibre thermoplastic (LTF) extrusion and compression moulding and the used fibres were sisal, banana, jute and flax, and the matrix was a polypropylene. The results showed that sisal composite shad the best impact properties and the longest fibres after the extrusion. Generally, flexural stiffness of the composites was increased with increased fibre content for all fibres, being highest for flax composites. The flexural strength was not affected by the addition of fibres because of the low compatibility. The addition of 2% weight maleated polypropylene significantly improved the composites properties. The electron microscopy study showed that sisal and banana fibres were several times coarser than flax and jute after processing. The fibre length measurements after the extrusion process showed that flax and jute fibres were shortest followed by banana and sisal (Chakravarty, 1974) [5].

**Advantages of Bast fibre plants**

Overall Advantages of Bast Plants:
In general, Bast plants possess the following benefits:

1. High tensile strength in Bast portions, especially in fiber varieties.
2. Bast plants have a relatively low specific gravity of 0.28 - 0.62, yielding an especially high specific strength, i.e. strength to weight ratio, (Kozlowski, Mieleniak, Przepiera, 1994).
3. Generally high fiber productivity rates, rivaling and even surpassing that of the most commercial tree species.
4. Potential for even greater productivity, Bast portions, and mechanical properties through focused genetic breeding.

**Overall Limitations of Bast Plants**

In general, Bast plants also have the following limitations:

1. Rotations at least every other year generally required.
2. Limited research for composite applications in North America.
3. Lack of related agricultural infrastructure in North America.
4. Relatively high absorption of moisture in core portion.
5. Diminished board properties when using core for particleboard.
6. Difficulty in handling long fiber bundle lengths for processing.
7. Difficulty in applying binder to long fiber bundle lengths.

**Retting of Bast fibres**

Mostly these Bast fibres are cemented to the adjacent cells inside the stem within the pectin, which is a form of carbohydrate. This process is called as retting or even can be termed as degumming. It is a chemical process for removing the non- cellulosic material that is attached to the fibres and even releases individual fibres. This is significantly called water retting, which is performed in an aqueous environment, and anaerobic, pectinolytic bacteria are responsible for the decomposition of pectic substances and the subsequent release of fibres. This process consistency yields high quality fibres. The chemical and enzyme retting offer substantially more control as compared to dew and water retting.

**Enzymatic retting**

Some might think it to be a modern method, but it goes a long back to the old days. This traditional method is achieved by the pectic enzymes produced by Bacteria. During the process of retting, the bacteria multiply and produce extracellular pectinases, these releases the Bast fibre from the surrounding cortex by dissolving the pectin. With a proper advancement in the technical tools, these enzymes can be commercially produced, making the enzymatic retting a popular choice for the production of long fibres (Achwal, 1994) [2].
As per the microbial analysis by Lang and Donenburg (2000), microbial pectolysis is one of the important factors in the decomposition of plant by breaking down the pectin polymer. During this process of degradation, the plant polysaccharides can be attacked by several enzymes. This process is being initiated by the pectic enzyme, as it is the most readily available. This type of enzyme has been used by many researchers for retting or degumming of plant fibres such as kenaf, ramie, flax and hemp.

**Properties of Bast fibres by retting**

These are going to be characterised as one of the long Bast fibres that are produced from hemp, jute, flex and kenaf obtained with using different retting processes. There is apparently cellulose, hemicelluloses and lignin are the main constitutes of Bast fibres. Bast fibres also include pectic materials, the main substances that bind the Bast fibres together. The total content of both cellulose and hemicelluloses that are 98% for Hemp, 80% both for jute and flax. While the Kenaf has the highest value in fibre length and diameter (Barish, 1984) [3].
In comparison to all Kenaf have only 71% of these polysaccharides. But flax and hemp are quite good source of fibres for textile appearance. Still kenaf is considered the most because of its high tensile strength among all kinds of Bast fibres. There are different retting processes implemented that are going to improve the strength of the Bast fibre. It is seen that in most laboratories, Bast fibres are used with different retting process as like some with water or sodium hydroxide and some with sodium benzoate. From all it is revealed that water retting is going to give the highest tensile strength.

**Conclusion**

With reference to the work and performances as mentioned previously, the composites reinforced with Bast fibres are found to have the best of tensile strength, flexuaral and impact properties than any other core component. The optimal strength of the Bast fibres are strong mechanically and it has been observed that the elongation at break for both composites decreases as the fibre content increased. From this is can be concluded that the Bast fibres are mechanically strong as the higher the cellulose content, the smaller fibre diameter and the longer fibre significantly increases the mechanical properties of the composite.
These Bast fibres have proficient intrinsic properties like that of mechanical strength, low weight and even are low in cost. They are mostly into use by the automobile industry. In comparison of being natural fibre these are composite material weighing about 30% less than the traditional wood based materials. The cause of these to cost less is it time taken to get ready for use. The car makers use natural fibres in- press molded thermoplastic panels for door inserts, shelves, seat backs etc.

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