

UTILIZATION AND VALUE ADDITION OF BANANA FIBRE - A REVIEW

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ABSTRACT

Banana (*Musa sapientum*) plant aptly called as 'kalpataru', a gigantic herb, a food fruit crop, an ancient species is cultivated all over the world. India is the largest producer of banana in the world. Banana plant not only gives the delicious fruit but it is also a source of textile fibre known as the banana fibre. The plant is grown in all kind of soils but most commonly found in hot tropical climate. All varieties of banana plants have fibres in abundance. These fibres are obtained after the fruit is harvested and fall in the group of bast fibres. This plant has been a good source for high quality textiles in many parts of the world, especially in Japan and Nepal. Banana fibre has the potentiality to be used in the manufacture of handicrafts, home decorative items, home furnishing items and paper. The paper made out of banana fibre has very good export potential. The fruitful utilization of these stems is therefore an important issue related to banana cultivation.

Key words: Banana, *Musa sapientum*, Banana fibre, Bast fibre, Pseudostem fibre, Fibre extraction.

Relatively high cost of synthetic fibres and health hazards, it becomes necessary to explore natural fibres. Quite a few numbers of alternative natural fibres are already established like ramie, mesta, sisal, roselle etc. However, the main objective of growing of these plants is production of fibre only. Banana (*Musa sp.*) is a well known important fruit crops grown in all over the world and can also be used as alternative source of useful quality fibres. The fruit bunches and leaves are main source of income, besides the leaves are used as bio plates for serving food in homes and functions.

It is estimated that after the harvesting of fruit, huge quantity (60 to 80 t/ha) of waste biomass (pseudostem, leaves, suckers etc.) is generated. Presently, this biomass is discarded as waste (Johnston, 2003). Considerable work has been done in the field of direct use and product development from banana fruits. However, not much attention has been focused on effective utilization of the huge biomass generated in the form of pseudostem, leaves, suckers etc. In India, presently this biomass is dumped on roadside or burnt or left in situ causing detrimental impact on environment. Though the

technologies for extraction of fibres and paper making from pseudostem are available, yet it has not been adopted by the industries mainly due to high transport cost. However, there exist a vast potential of extracting fibres from pseudostem. It is estimated that annually 17,000 tonnes of fibre can be extracted from the waste portion of the banana plant, valued at roughly Rs. 85 crore (Rs. 50,000 per tonne).

In India the quantity and quality of fibres show wide variability with cultivars. Mostly the fibre is extracted by manual process and the yield of fibre is very low and this kind of manual process needs skilled labours. After a brief study of banana fibre extraction, CTRI, Rajamundry has developed a banana fibre extracting Machine, which can be easily operated by an unskilled labour giving maximum output.

The fibre extracted from banana pseudostem could not command proper market owing to its restricted use in cottage industries. There appears to be good scope of profitable use of this fibre in textile and paper industries on commercial scale.

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TABLE 1: State wise banana cultivation belt in India.

State	Banana Growing belts
Andhra Pradesh	East Godavari, West Godavari, Kurnool, Cuddapah
Assam	Goalpara, Nagaon, Sonitpur, Foothills of Garo hills
Bihar	Muzaffarpur, Samastipur, Purnia, Katihar, Vaishali, Bhagalpur, Darbhanga, Madhubani, Sitamarhi
Gujarat	Surat, Vadodara, Ananad, Kheda, Junagadh, Narmada, Bharuch
Jharkhand	Ranchi, Sahebganj
Karnataka	Bangalore, Chitradurga, Shioroga, Hassan, Chikka Magloor
Kerala	Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Kottayam, Idukki, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Wynadu, Kannur, Kasargod
Madhya Pradesh	Khandwa, Badwani, Khargaon, Dhar
Maharashtra	Jalgaon, Ahmednagar, Buldhana, Pune, Wardha, Dhule, Nanded, Parbani, Nandurbar, Satara, Sangli, Osmanabad, Buldhana, Akola, Yeothmal, Amravati, Thane, Kulara, Alibag
Orissa	Ganjam, Puri, Khurda, Gajpati, Cuttack, Dhenkanal, Angul, Sundargarh, Sambalpur, Bargarh, Deogarh, Koraput, Keonjhar, Raygada, Mayurbhanj
Tamil Nadu	Thoothukudi, Tiruchirapalli, Coimbatore, Tirunelveli, Karur, Erode, Kanniyakumari
West Bengal	Hooghly, Nadia, North 24 Parganas

Source: Fibre Policy Sub Group Report, 2008.

Not only this, but number of high value products like carpets, coasters bags and different types of handicrafts can also be developed from banana pseudostem. In brief, banana fibre has a bright future and arena to perform in the forthcoming years.

International Scenario – Banana Fibre: As such no data is available on global banana fibre production. However, data related to banana production and trade can be taken. India is the largest producer of banana with 32.8% share in total global production of banana in 2008 (Fig.2). The other major banana producing countries are China, Brazil, Ecuador and Indonesia.

Ecuador was the largest exporter of banana in 2007. The other major exporting countries in 2007 were Costa Rica, Colombia, Guatemala and Belgium. On the other end, Germany was the biggest importer of banana in 2007. The other major importing countries in 2007 were Belgium, Japan, Italy, France, Canada and China.

Philippines and Japan are the major banana fibre producing countries for large scale manufacturing of textile items made from banana fibre. Philippines is also exporting huge quantity of readymade garments manufactured from banana fibre to Japan, Singapore, Taiwan and all far East Asian countries. In India, banana fibre is primarily used in cottage industry situated in Southern India.

Present Status In India: India is the biggest producer of banana across the globe (Mahapatra et al, 2010). The following table depicts the state wise

banana cultivation belts (Table 1). India produced 23.2 million tonnes of banana with a productivity of 35.9 tonnes per hectare in FY08.

Fibre Extraction From Banana: Banana Fibre is extracted from Banana pseudostem bark. The trunk is peeled and brown-green skin is thrown away retaining the cleaner or white portion which is processed further. There are two methods of banana fibre extraction, manual stripping and machine stripping (by mechanical decorticator):-

Manual stripping: Banana fibre is extracted from waste stalk of banana plant. Generally banana fibre is situated near to the outer surface of the sheath and can be peeled-off easily in ribbons of strips of 5-8 cm wide and 2-4 mm thick along the entire length of the sheath. The stripping process is known as tuxying and the strips are called tuxies. There are two methods of tuxying as prevalent in Philippines.

(a) Bacnis method.

In this method, trunks are pulled apart and the sheath is separated as per their position in stalk. Thereafter, they are flattened and the fibre is stripped from the stem by cutting the pulpy part and pulling away the tuxy.

(b) Loenit method.

In this method tuxies are pulled off the stalk from one sheath at a time.

After stripping, tuxies are bundled into bundles of 23-27 kg and brought to the stripping knife for cleaning. At last fibre is air dried and bundled for subsequent grading and bailing.

TABLE 2: State wise banana production in India during 2007-08

State	Production in tones	Production share %	Major varieties grown
Andra Pradesh	2254	9.7	Dwarf Cavendishi, Robusta, Poovan, Rasthali, Chakkarekeli, Thellachakkarekeli, Karpoora Poovan, Amritpant
Assam	610	2.6	Dwarf Cavendishi (Jahaji), Chini Champa, Malbhog, Borjahaji (Robusta), Honda, Manjahaji, Chinia, Kanchkol, Bhimkol, Jatikol, Digiowa, Kulpait, Bharatmoni
Bihar	1329	5.7	Dwarf Cavendishi, Alpan, Chinia, Chini Champa, Malbhig, Muthia, Kothia, Gauria Thellachakkarekeli, Karpoora Poovan, Monthan, Amritpant
Gujarat	3158	13.6	Dwarf Cavendishi, Srimati, Mahalaxmi, Mahabanana, Locatan, Harichal G-9, Basrai
Jharkhand	51.6	0.2	Basrai, Singapuri
Karnataka	1513	6.5	G-9, Elaki, Dwarf Cavendishi, Robusta, Nendran, Poovan, Monthan, Elakkibale
Kerala	494	2.1	Nendran, Palayankodan, Rasthali, Monthan, Red Banana, Robusta
Madhya Pradesh	788	3.4	Basrai
Maharashtra	4963	21.4	Grand Naine, Dwarf Cavendishi, Basrai, Robusta, Lal Velchi, Safed Velchi and Nendran
Odisha	297	1.3	Dwarf Cavendishi, Robusta, Champa Patakapura (Rasthali)
Tamil Nadu	6117	26.4	G-9, Robusta, Virupakshi, Red Banana, Povon, Elakki, Rasthali, Robusta, Karpooravalli, Sakkai, Matti, Red Banana, Peyam
West Bengal	892	3.8	Dwarf Cavendishi, Mortaman, Champa, amrit Sagar, Singapuri, Chini Champa, Giant Governor
Others	737	3.2	-

Source: Mahapatra *et al.*, 2010, J. Sci. Ind. Res. 69: 323-329.

TABLE 3 : Composition of banana pseudostem fibre.

Parameters	Banana	Jute (<i>Chorchrus capsularis</i>)	Jute (<i>Chorchrus olitorius</i>)
Major constituents (%)			
α -Cellulose	61.5	61.0	60.7
Pentosan	14.9	15.9	15.6
Uronic anhydride	5.3	-	5.9
Acetyl content	2.8	2.9	3.5
Lignin content	9.7	13.2	12.5
Minor constituents (%)			
Fat & Wax	1.4	0.9	1.0
Nitrogenous matter	1.6	1.56	1.87
Ash	4.8	0.5	0.79
Monosaccharide Constituents (%)			
Glucose	60.8	-	62.2
Xylose	11.0	-	9.1
Mannose	3.2	-	1.2
Galactose	0.4	-	1.4
Arabinose	4.1	-	0.4
Rhamnose	0.5	-	-
Degree of polymerization α -Cellulose	1300	-	1150

Mechanical Extraction of Banana Fibre: The manual (or) semi mechanical extraction of banana fibre was tedious, time consuming and causing damage to the fibre. So after intensive study and research a simple low cost user friendly CTRI Banana Fibre Extractor machine was designed and

developed for extracting banana fibre mechanically from banana pseudostems, leaf stalks and flower stalks.

The method is simple and the machine is efficient to extract fibre from banana stems. It is very user friendly. Anyone can operate it with a training of just 30 minutes. This machine reduces the drudgery of manual extraction of fibre and provides a clean working environment. It will help the workers to produce more fibres and get increased income.

The machine consists of a rigid frame on which the roller rotates. The roller consists of twenty seven mild steel or stainless steel horizontal blades (6 mm size) with blunt edges all around and rotates on a free moving shaft. The roller could be driven by a standard one horse power single phase electric motor by belt and pulley arrangement, which is fixed over the rigid frame. The machine reduces drudgery and increases fibre production by 20-fold as compared to manual process. An additional net income of Rs.12,000/- per ha is assured to the banana cultivators.

In this method trunks are cut into sections of 120-180 cm in length. The sections (one half the length at a time) are then crushed between rolls and the pulpy tissues are separated by two large revolving drums, the rim of which are fitted with scrapping blade which peel-off the sheath while it is pressed against a bed plate, oven dried, graded and baled.

TABLE 4: Banana fibre prices vis-à-vis other natural fibre prices in India (Mukhopadhyay *et al.*, 2008)

Natural fibre	Prices (US \$/ kg)
Banana	0.43- 0.81
Hemp	0.15- 0.60
Kenaf	0.15-0.30
Flax	0.15-0.21

The salient features of this machine are :

Very safe to operate

User friendly.

Training to operate can be given in 30 Minutes. So, even unskilled worker can learn and operate without any difficulty.

A good substitute for manual extraction of Banana fibre.

Fibre can be extracted in all types of banana pseudostems, leaf stalks and flower stalks.

High quality fibres can be produced.

Maintenance cost is very low.

Necessary spare parts are easily available in open market and easily available.

The extracted fibres are sun-dried which whitens the fibre. Once dried, the fibres are ready for knotting. A bunch of fibres are mounted or clamped on a stick to facilitate segregation. Each fibre is separated according to fibre sizes and grouped accordingly. To knot the fibre, each fibre is separated and knotted to the end of another fibre manually. The separation and knotting is repeated until bunches of unknotted fibres are finished to form a long continuous strand. This fibre can now be used for making various products.

Characteristics of Banana Fibre: Banana fibre is a natural bast fibre. It has its own physical and chemical characteristics and many other properties that make it a fine quality fibre.

Appearance of banana fibre is similar to that of bamboo fibre and ramie fibre, but its fineness and spinnability is better than the two.

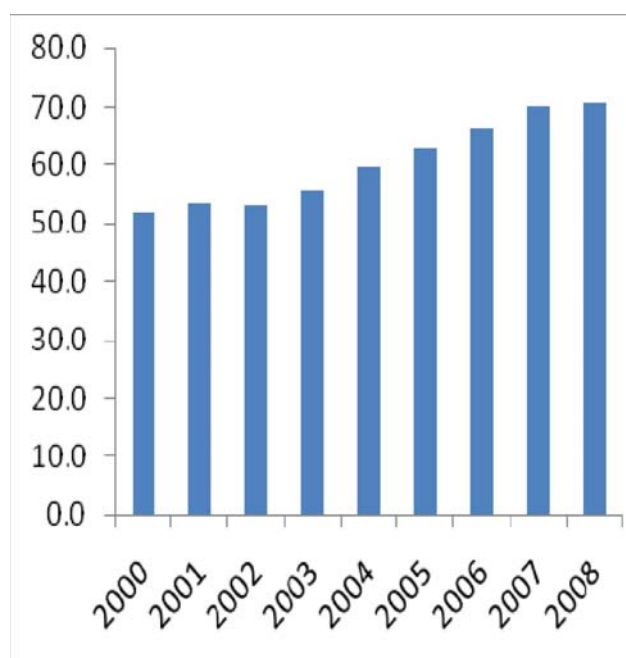
The chemical composition of banana fibre is cellulose, hemicellulose and lignin.

It is highly strong fibre.

It has lower elongation.

It has somewhat shiny appearance depending upon the extraction and spinning process.

It is light weight.



Source: FAO Stats

FIG.1: Overall global production trend in banana (in million tonnes).

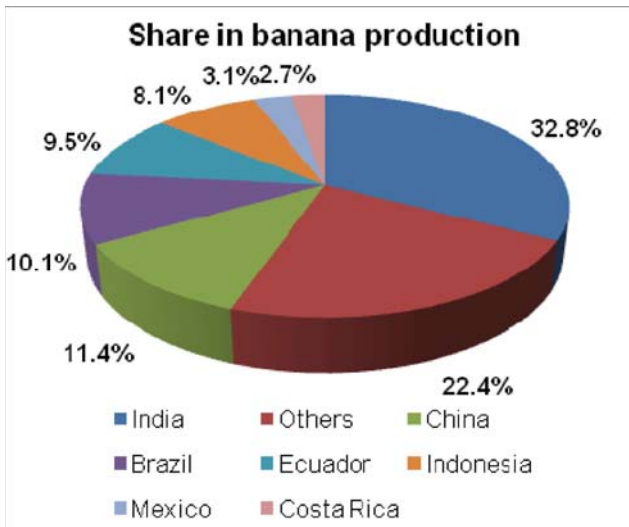
It has strong moisture absorption quality. It absorbs as well as releases moisture very fast.

It is biodegradable and has no negative effect on environment and thus can be categorized as eco-friendly fibre.

Its average fineness is 2400Nm.

It can be spun through almost all the methods of spinning including ring spinning, open-end spinning, bast fibre spinning and semi-worsted spinning among others.

Chemical Composition Of Banana Fibre: Bast fibres, like banana are complex in structure. They are generally lignocellulosic consisting of helically wound cellulose microfibrils in amorphous matrix of lignin and hemicellulose. For mechanical properties along with microfibril angle, the cellulose content serves as a deciding factor. A high cellulose content and low microfibril angle impart desirable mechanical properties for bast fibres. Lignins are composed of nine carbon units derived from substituted cinnamyl alcohol; that is, coumaryl, coniferyl, and syringyl alcohols. Lignins are associated with the hemicelluloses and play an



Source: FAO Stats

FIG. 2: Share of different countries in Banana production.

important role in the natural decay resistance of the lignocellulosic material. The composition of banana pseudostem obtained by elemental analysis has been determined by many authors (Bilba *et.al* 2007 ; Nag and Saha, 2009) (Table 3)

Problems And Prospects Of Banana Fibre:

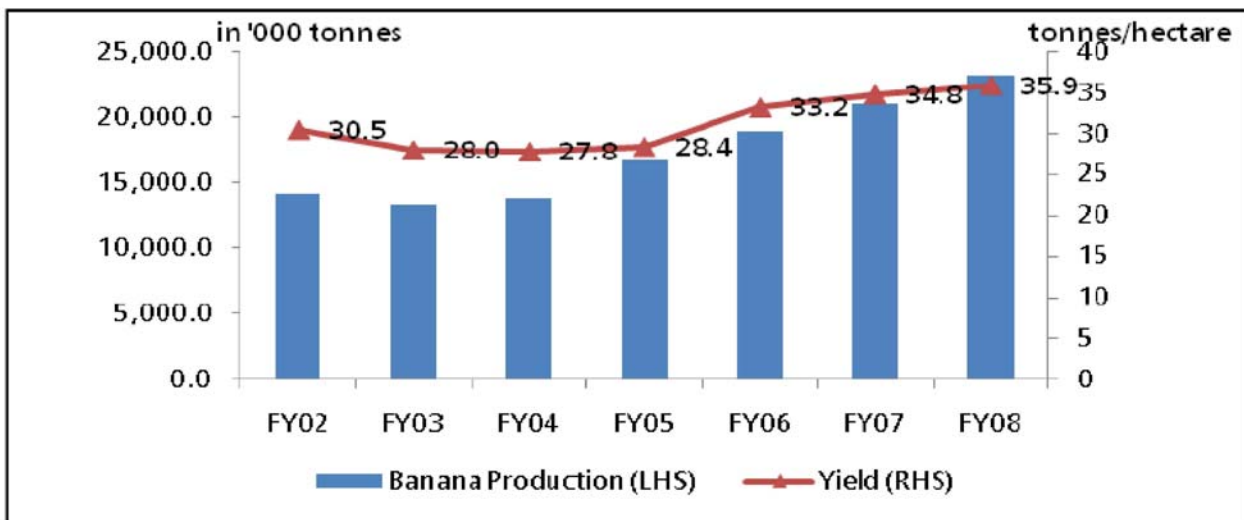
Application of banana fibre for manufacturing textiles is a new concept in India. In India, only 10% of the banana waste (Pseudo stems) is used for extracting the fibre and rest is wasted. There is no

standard way to extract the banana fibres in the country resulting in irregular demand supply situation, which finally leads to higher prices of banana fibres (Mohanty *et al.*, 2001) against other natural fibres for end users in the country.

The main reason behind under-utilization of banana fibre is the lack of sufficient scientific data on this fibre, except information regarding its chemical constituents. In India, banana fibre is primarily extracted manually. The manual extraction process causes low yield and high labor cost as this type of manual process needs skilled labour. Machine extraction process has following distinct advantages over manual extraction process.

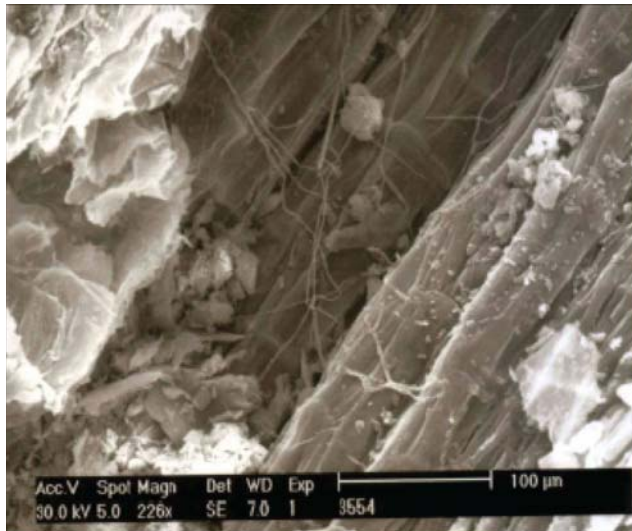
Presently, waste banana stems pose problem of disposal and are available almost free of cost in Central and South Gujarat. In recent past India has developed banana Fibre Separator Machine. This machine produces silk grade fibre from banana agricultural waste. The silk grade fibre is widely used by handicrafts and textile industry.

Application Of Banana Fibre: In the recent past, banana fibre had a very limited application and was primarily used for making items like ropes, mats and some other composite materials. With the increasing environmental awareness and growing importance of unfriendly fabrics, banana fibre has also been recognized for all its good qualities and now its application is increasing in other fields too such as apparel garments and home furnishings. However,



Source: indiastat.com

FIG.3: Banana production in India and its yield.



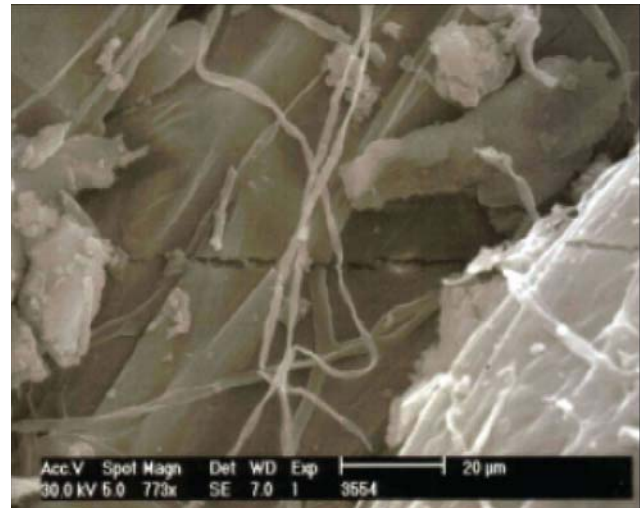
(Courtesy: M. A. Maleque, F. Y. Belal)

FIG.4: Scanning electron micrograph of banana woven fabric epoxy composite after tensile test at 226×magnification.

in Japan, it is being used for making traditional dresses like kimono and Kagoshima since the Edo period (1600-1868). Due to its being lightweight and comfortable to wear, it is still preferred by people there as summer wear. Banana fibre is also used to make fine cushion covers, neckties, bags, table cloths, curtains etc. Rugs made from banana silk yarn fibres are also very popular world over.

Banana fibre is a new textile fibre. It is greener, more detailed, shinier, and thinner. Banana fibre yarn can be spun to 100 NM. Banana fibre fabric is very thin, glossy, but still has some flexibility. Banana fibre is lustrous and light weight. These fibres are used in spinning highly textural yarn, used for knitting, weaving, embellishment and other decorative purposes. Apparels made from banana fibre denote aristocratic status in some countries. These fibres are used in Europe for making socks. In Philippines, these fibres are used for making garments. In Japan, cultivating banana for cloth making has been a traditional process and has been followed since 13th century. Polypropylene reinforced with banana fibres is used by automobile companies for making under floor protection panels in luxurious cars like Mercedes.

Potential Applications: Banana fibre is better than bamboo and ramie fibre in accordance to their



(Courtesy: M. A. Maleque, F. Y. Belal)

FIG. 5: Scanning electron micrograph of banana woven fabric epoxy composite after tensile test at 773×magnification.

performance. It possesses many virtues like high tensile strength, luster, light weight and good moisture absorption capacity. Banana fibres are mostly used in making handicrafts and home decorative. They have a wide variety of applications in making various products like paper bags, filter paper, greeting cards, decorative papers, pen stands, lamp shades and many more. These products have a potential market. Papers made from banana fibres have good market in 25 international countries including Europe. These papers are chemical free and possess Eco friendly qualities, with longevity of 700 years. Currently companies make limited application of banana fibres in making mats, ropes and composite materials.

Banana fibre has also got very wide usage in the units like, 100% chemical free tissue paper, high quality filter papers, paper bags, craft papers, good quality greeting cards, wedding cards, carry bags, nursery pouches, art papers, decorative papers, tissue papers, bond papers, paper products like pen stands, table decorative, lamp shades etc., Products that are made out of banana fibre have very good market.

Banana fibre is used in manufacturing industries of handicrafts, home decorative, door mats, table mats,

pooja and meditation mats. Paper made out of banana fibre is having very good export potential.

Banana Fibre Based Composites: Banana fibre can be employed as reinforcing polymer for preparation of composites. Although scanty literatures are available in these matter. Laly *et al.* (2003) have investigated banana fibre reinforced polyester composites and found that the optimum content of banana fibre is 40% through dynamic mechanical analysis. Corbiere-Nicollier *et al.* (2001) were investigated mechanical properties of banana fibre cement composites physically and mechanically. There has been reports that kraft pulped banana fibre composite has good flexural strength. In addition, short banana fibre reinforced polyester composite was studied by Pothan *et al.* (1997); which concentrated on the effect of fibre length and fibre content. The maximum tensile strength was observed at 30 mm fibre length while maximum impact strength was observed at 40 mm fibre length. Incorporation of 40% untreated fibre provides a 20% increase in the tensile strength and a 34% increase in impact strength. The banana fibre and glass fibre with varying fibre length and fibre content were tested by Joseph *et al.* (2002). The analysis of tensile, flexural, and impact properties of these composites revealed that composites with good strength could be successfully developed using banana fibre as the reinforcing agent. As the banana pseudostem is considered as a waste and available in plenty in a country like India, the banana pseudo-stem fibre woven fabric reinforcement polymer composites of high-strength can be used in a broad range of applications.

Fracture Surface Study by SEM: Pseudo stem banana fibre can be used as reinforced material for fibre based epoxy composites. Maleque and Belal (2007) studied the tensile, flexural, and impact properties of pseudostem banana fibre reinforced epoxy composites. The pseudo-stem banana woven fabric epoxy composite on fracture surface study changes in the following way as depicted in Figures 4 and 5 . It can be seen from the SEM micrograph of the fracture surface, that the banana

fibre composite exhibits a ductile appearance with minimum plastic deformation after the tensile test. A fracture profile in the form of a ridge appears on the surface with the presence of continuous banana fibres. Higher magnification (Figure 10) also showed the continuous banana fibres with a fractured epoxy matrix, which again depicts the ductile characteristics and high strength carrying capacity of the fibres.

Innovation In Extraction Process Of Banana Fibre: The essentially hand driven process of extracting banana fibre is now set to change with the invention of the Banana Fibre Separator Machine. The machine has been developed in India by Central Tobacco Research Institute, Rajamundry. One more interesting fact associated with the development of this machine is that it uses the agriculture waste of banana harvests to produce silk grade fibre. These silk grade fibres are of immense help to the handicrafts and textile industry. Therefore, banana waste what was previously considered an agricultural waste is now converted to a raw material for good quality silk grade fibre yarn. Further investigation in the field of extraction machinery and process development is required for rightful application of banana fibre for the future generation.

Epilogue: Although banana is considered as one of the important fruit crop, its identity as fibre crop is still not established in the rural sector of India. That is why a huge amount of banana plant is wasted after harvesting the fruits. The fibre from banana is a high in quality and its fibre character and chemical composition reveals that it has a very high potentiality to be established as fibre yielding crop. Every year India loses crores of rupees due to lack of awareness to the rural people as well as unavailability of the proper technology for extraction of fibre. Here lies the responsibility of technologists as well as the actual technology user. It is obvious that over use of synthetics has raised tremendous concern about our environment. Only natural fibres can show us new hope for the future as the petroleum reserve of the earth is dwindling. Banana fibre, therefore can prove the worthy of it in the forthcoming days.

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