International Journal of Bioresource Science
Citation: IJBS: **09**(02): 173-178, December 2022
DOI: 10.30954/2347-9655.02.2022.15

ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

Research Paper

Properties, Processing and Application of Banana Fibre

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Received: 02-10-2022 **Revised:** 23-11-2022 **Accepted:** 09-12-2022

ABSTRACT

Banana (*Musa Sapientum*) plant is cultivated in many countries in the world for the production fruits, which is one of the important fruits. After harvesting the fruit, the other parts of plant biomass are commonly disposed of that causes environmental pollution. The present article highlights the extraction of fibre from the banana pseudostem followed by its details physical and chemical characterization. Banana fibre can be blended with jute fibre in different ratios for development of numbers of apparel and home textile products, like jackets, sofa cover, window curtain, pillow cover, etc. Chemical treatment of banana fibre and jute fibre prior to yarn and fabric formation could improve its strength. Banana pseudostem sap (BPS) can be used as an active ingredient for natural dye, mordant, UV protective and flame retardant finishing of textile. The banana fibre can be judiciously used for making quality paper and micro-crystalline cellulose powder.

HIGHLIGHTS

- Development of banana/jute fibres blended yarn.
- Jute rich samples showed better properties.
- Chemical modification improved yarn properties.
- Banana fibre suitable for diversified applications.

Keywords: Fibre, blended yarn, apparel textile, home textile, banana

Among the various crops, banana is widely cultivated in India over an area of 7.1 lakh ha. The plant as well as fruit is grown in many states of India, namely Andhra Pradesh, Assam, Gujarat, Jharkhand, Karnataka, Kerala, etc. The banana plant has a juicy thick stem, commonly known as pseudostem and its production is about 60-80 t/ha. The pseudostem of banana plant and/or the extracted juice from it are commonly considered as agro-waste, having no techno-economic utility. In the last few years, various R&D projects have been carried out in India and other parts of the world to use such bio-waste product in a meaningful way. Mainly, the plant stem is consisted of liquid sap, textile grade fibre, scutcher and central core part. As far as the main usages are concerned, the fibrous part obtained from the pseudostem can be used for making textile yarn & fabrics, high quality handmade paper and different attractive handicrafts. Extraction of microcrystalline cellulose from banana fibre is an important pathway for value addition to this waste for industrial applications. The scutcher of the pseudostem normally generated in huge quantity (30-35 t/ha), has been used for vermicomposting, making handmade papers and boards for various applications. The central core of the banana pseudostem has the different uses like making vitamin rich candy, pickles and also as vegetable. ICAR-National Institute of Natural

How to cite this article: Samanta, K.K. and Chattopadhyay, S.N. (2022). Properties, Processing and Application of Banana Fibre. *Int. J. Bioresource Sci.*, **09**(02): 173-178.

Source of Support: None; **Conflict of Interest:** None

Fibre Engineering and Technology, Kolkata has been executing several research activities on making yarn, fabric, technical textile, industrial textile, handicrafts, etc. by utilizing jute and allied fibres, like banana, flax, ramie, pineapple, sisal, coir, nettle and mesta (Chattopadhyay *et al.* 2020; Roy *et al.* 2015; Samanta *et al.* 2021). In this direction, both the banana and jute being extracted from the plant stem, are composed of cellulose, hemicellulose and lignin, but there is a variation in these three constituents. Banana fibre is coarse and stiffer than the jute and its exhibits the important functional properties like fire retardant, ultraviolet protection and antibacterial (Pandey 1993; Wei 2009; Horrocks 1986) with the suitability of making coarse yarns. Therefore, suitable pre-treatment and requisite chemical intervention are suggested for many of the lignocellulosic fibres (Varma 1986; Shore 1990) to amenable them improvement fineness and softness. Such enhancement could increase their acceptability in production of blended yarns and fabric in blending with jute in different proportion. It has been reported that blending of two or more fibres at carding, drawing, or spinning stage could improve the yarn attributes, due to utilization of unique characteristic of individual fibes (Jeffries 1988; Smith 1989; Bajaj 1992). Very recently, as an output of research on textile material, an eco-friendly technology has been developed for making different textiles fire retardant by using BPS at appropriate level. Furthermore, to flame retardancy, the treated cellulosic and ligno-cellulosic textiles could exhibit ultraviolet ray (UV-rays) protection efficacy also. This present article summarizes the value-added uses of the banana pseudostem based on available literatures, which may be useful to its stakeholders, like farmers, textile technocrats, botanical and pharmaceutical researchers, entrepreneurs, scientist and the student community.

Extraction and characterization of fibre

Fibre can be extracted from the banana pseudostem after the separation of individual sheaths one by one from the whole length of pseudostem. The banana stem is consisted of closely packed leaf-sheaths embedded, from which fibre is extracted either manually or using machine. After harvesting the fruit, the pseudostem has no regular use. The sheath of the stem is generally scraped by a blunt knife or decorticated to obtain the fibre. The fibre is later washed with water or a chemical to prevent it from brittleness. Only a small quantity of fibre is manually extracted to meet demand of Indian Cottage Industry for making handbags, ropes, twines, fancy articles, cushioning material, packing etc. The yield of fibre from the pseudostem of banana plant is about 0.75 to 1.0%, as reported. From the banana plant trunk, the fibre is extracted by scutching and washing, without washing or washing in diluted chemicals. After extraction, the banana fibre was characterized to study their physical, chemical and optical properties and those characters were compared with jute fibre. It is clear from the Table 1 that banana fibres are whiter and brighter than jute fibre, which is of golden colour (Chattopadhyay *et al.* 2020). It can be seen from Table 1 that banana fibre is quite coarser than the jute fibre, which is clear from the 'tex' and diameter values. Bundle tenacity of banana fibre is little lower than the jute fibre.

Table 1: Physical, optical and mechanical properties of banana and jute fibres (Chattopadhyay *et al.* 2020)

Different treatment and fibres	K/S value	Whiteness Index (WI)	Bundle tenacity (g/tex)	Fibre fineness (tex)	Fibre diameter (μ)
Jute fibre	2.22	50.3	27.1	3.4	110
Extracted banana fibre	1.69	53.8	24.4	8.3	160-180
Bio-scoured jute	1.56	56.1	24.2	2.8	100
Bio-scoured banana	1.32	58.4	20.4	6.8	150
Bio-scoured-bleached jute	0.48	82.4	21.8	2.3	80
Bio-scoured-bleached banana	0.50	81.3	18.3	6.0	140
Bleached jute	0.31	80.2	22.3	2.5	90
Bleached banana	0.52	78.1	19.4	6.2	150

Wet processes of banana fibre, like scouring and bleaching lead to loss in fibre weight in concurrence with improvement in fibre's fineness, whiteness and brightness. Both the fibres i.e., jute and banana after chemical treatment becomes more finer and whiter (in Hunter scale), with an approximately 20% loss in tenacity value.

Chemical constituents in the jute as well as banana were estimated and compared, as indicated in Table 2. It can be seen that α-cellulose percentage are almost same in both the fibres, but hemi-cellulose is found to be more in banana fibre. In-spite of similar cellulose content in both the fibres, jute fibre showed more crystallinity, resulting higher strength (Table 1). It was also observed that jute has more crystallinity percentage as compared to banana fibre. The jute fibre possesses more amount of lignin, enhancing it rigidity.

Table 2: Cellulose, hemicellulose and lignin percentage in jute and banana fibres (Chattopadhyay *et al.* 2020)

Fibre	α-cellulose (%)	Hemicellulose (%)	Lignin (%)	Crystallinity (%)
Banana fibre	60.70	26.12	8.7	56
Jute fibre	61.10	18.80	13.2	67

Development jute/banana blended textile

The banana fibre is allied to jute and thus can be processed in jute spinning system with some adjustments, either individually or blends with other natural fibres like jute, sisal, and sunnhemp. In-fact, it is needed to staple the banana fibres for effective mechanical processing for yarn development in jute machineries. The resulting yarn is expected to show some improved property performance in terms of tenacity, extension, lustr etc. The possibility of making blended yarn in mixing with jute fibre was studied by utilizing jute spinning machineries, consist of softener, breaker card, finisher card, drawing machine and spinning machine (Sinha, 1974a&b). At ICAR-NINFET, Kolkata thorough investigations have been made on various areas of banana fibre and its residual biomass, in term of development extractor, fibre properties assessment, making of pure and blended yarns, development fabric & products, and colouration of fibre, yarn and fabric (Chattopadhyay *et al.* 2020; Roy *et al.* 2015; Samanta *et al.* 2015; Nayak *et al.* 2016). An attempt was made to produce yarn of 6 lb/spyndle count with 5 twist per inch in apron draft spinning machine from the only banana fibres and blended yarns keeping the jute to banana fibres blend ratio of 75/25, 50/50 and 25/75 (Roy *et al.* 2015). However, the spinning performance of 100% banana and jute/banana with blend ratio of 25/75 was not very much promising. After several spinning trails, it was noticed that the yarns of 8 lb/spyndle with 4 twist per inch and 10 lb/spyndle yarn with 3.4 twist per inch in slip draft spinning system was satisfactory for production of blended yarn in 75/25, 50/50 and 25/75 blend ratios. It was also experiencing that 100% banana yarn of count 10 lb/spyndle with 3.4 twist per inch in slip draft spinning frame was possible to make. It was found that 100% banana fibre can be processed smoothly in jute processing machineries and can be spun to grist of 10 lb (345 tex) and above. Sample fabric has been woven with ornamental designs using cotton yarn in warp and the jute/banana (75:25) fibre blended dyed 6 lb yarn in the weft direction. Total banana fibre in the fabric was approximately 20%.

Table 3: Tensile properties of 6 lb (207 tex) 100% jute, 100% banana and blended yarns (Roy *et al.* 2015)

Different blended yarns	Tenacity (cN/tex)	Tensile strain (%)	Work of rupture, (mJ/tex-m)
Pure jute yarn	10.93	1.98	0.96
Jute/banana yarn (75/25)	10.66	1.23	0.65
Jute/banana yarn (50/500	8.18	1.73	0.72
Jute/banana yarn (25/75)	7.34	1.77	0.63
Pure banana yarn	6.03	1.80	0.53

Effect of fibre pre-treatment

In order to improve the softness and other properties of jute fibre, it was subjected to treatment in the presence of different chemicals keeping material-to-liquor ratio at 1:10 namely, cellulase enzyme, xylanase enzyme, and non-ionic surface-active agent, maintaining the pH value in between 7-9 (Chattopadhyay *et al.* 2020). Jute fibre before and after bio-scouring was as considered for bleaching treatment with hydrogen peroxide at pH of 10 for 90 min at 80-85 °C. As produced as well as extracted both the ligno-cellulosic banana and jute fibres were

Table 4: Mechanical properties of banana and jute fibres blended yarns produced from untreated and bleached jute and banana fibres (Chattopadhyay *et al.* 2020)

Different samples	Max. Load (N)	Tenacity (cN/tex)	Strain (%)	Total Energy (mJ)	Breaking modulus (cN/tex)
Jute/banana (75/25) blended yarn	16.9	6.45	1.63	84	397
Jute/banana (75/25) blended yarn from bleached fibres	28.31	10.64	1.77	487	142
Jute/banana (50/50) blended yarn	9.97	3.80	1.49	51	261
Jute/banana (50/50) blended yarn from bleached fibres	20.50	7.62	1.54	434	94
Jute/banana (25/75) blended yarn	11.5	3.96	1.99	77	201
Jute/banana (25/75) blended yarn from bleached fibres	22.14	7.94	1.47	479	100

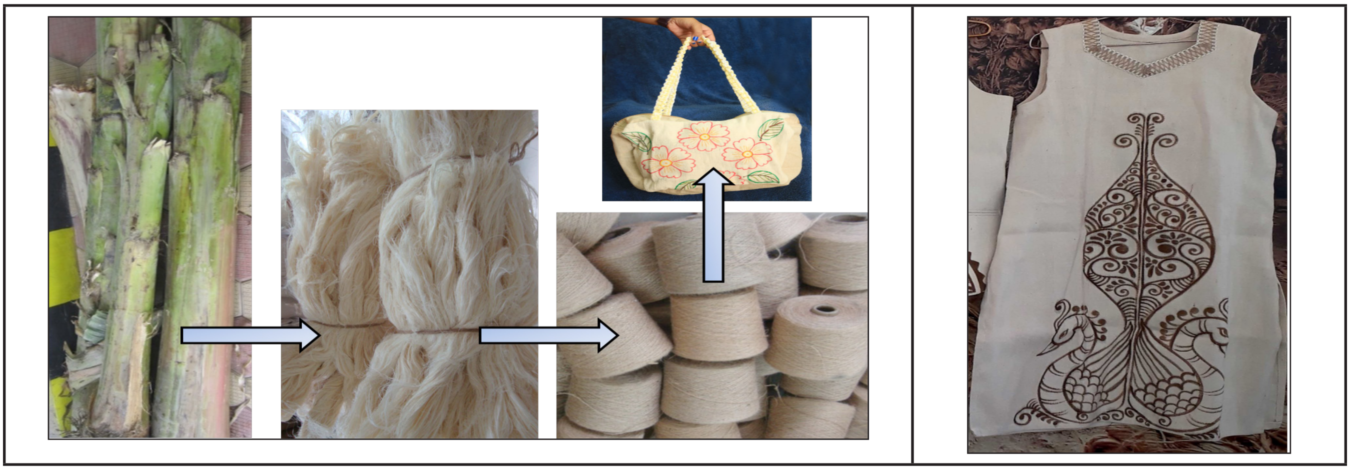

Fig. 1: Process of development of apparel and utility textile products from banana and jute fibres

blended to produce yarns with count 8 lb/spyndle keeping the banana to jute fibres blend ratio of 75:25, 50:50 and 25:75 in jute spinning system. In the same way, banana/jute blended yarn of 8 lb/spyndle were also developed from the bleached jute and banana fibres maintaining the above three blend ratios in order to study the effect fibre chemical pre-treatment in the blended yarn and fabric properties.

It can be seen from Table 4 that the yarns produced from the bleached banana and jute fibres possess notably higher tenacity as compared to similar yarns, developed from the grey jute and banana fibres. A similar trend was also observed all the yarns produced from the jute/banana fibres with different blend ratios of 25/75; 50/50; 75/25. Out of these three blended yarns, the jute/banana (75/25) yarn showed the maximum value in its physical properties in terms of tenacity, maximum load, breaking modulus and energy to break, when prepared from grey as well as bleached fibre. Figure 1 shows picture of handloom prepared jute/banana blended fabric.

In order to produce banana/jute blended yarn with smooth surface and soft feel, regenerated viscose fibre was introduced as a third component to produce ternary blended yarn. Both the jute and banana fibres were cut into one feet length, then bleached with peracetic acid. Such fibres were then used to produce ternary blended yarn of count 4 lb/spyndle, 6 lb/spyndle and 8 lb/spyndle in jute spinning system with jute: banana: viscose fibres blend ratio of 35:35:30 (Chattopadhyay *et al.* 2021). The optical characteristics of the individual fibres and the resultant yarn have been measured. It was found that the whiteness and brightness indices of the yarns are lower than that of the individual bleached fibres, happened due to the spinning effect. With increasing the count of the yarn from 4 lb/spyndle to 8 lb/spyndle, tenacity increases marginally from 5.27 cN/tex to 6.07 cN/tex. However, it was interesting to note that the initial modulus profoundly decreases from 500 to 309 cN/tex for the increase in yarn count from 4 to 8 lb/spyndle.

Other applications of banana fibre

In order to find out the possibility of using banana fibre as a raw material for paper making, series of experiments were conducted in a paper mill under NAIP on Banana project (https://naip.icar.gov.in/download/c2-208701.pdf). Those trials were conducted for optimizing the pulping, cooking time, chemical doses, temperature, bath ratio and bleaching parameters. It was found that banana fibre is easily bleachable and has good bleaching response with achievable 88% ISO brightness in bleached pulp. Un-bleached and bleached papers developed were tested. The brightness of bleached paper is 73.8% i.e., low in comparison to 87-88% brightness, measured for pulp sample. Paper can be made of high brightness with banana fibre pulp. The strength properties of hand sheets in terms of double fold and bursting factor are good and showing good paper making potential. The breaking length of unbleached paper was almost double as compared to bleached paper.

Banana fibre is rich in cellulose content, thus can be considered as a potential resource for preparation of microcrystalline cellulose (MCC). An effort was made under above project to standardize the bio-chemical route for the preparation of MCC from banana fibre and along with their detail properties evaluation. Moisture content of banana fibre MCC is 5.3%, which is in close to the commercial MCC (5%) sample. The cellulose content in MCC, prepared from the banana fibre is 99.0%, which is similar to commercial MCC. The particle sizes of MCC were measured to be 30 μm for the banana fibre based and 80 μm for the commercial samples, respectively. Size depends upon the extent of degradation of cellulose molecule. Both the prepared cellulose powder as well as commercial MCC are having similar characteristics in terms of solubility in water, dilute alkali, dilute acid, organic solvent and groundnut oil, which are as per standards of Pharmacopoeia of India.

CONCLUSION

Banana fibre as well as liquid sap can be extracted using indigenously developed low-cost fibre extraction machines. There is an opportunity for small scale entrepreneurs for venturing into banana pseudostem processing and value addition sectors, viz. extraction of fibre, vermicomposting, handmade paper and liquid sap extraction. Though the extracted banana fibre was coarser than that of jute fibre, its fineness could be improved by chemical intervention. Banana fibre was blended with jute fibre in different ratios, where the jute rich blended yarn as well as fabric showed higher mechanical properties. Such properties could be further enhanced with the production of yarn and fabric from the bioscoured-bleached fibres. The banana fibre can also be used for making quality paper and micro-crystalline cellulose powder (MCC).

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