J. Hort. Sci.
Vol. 1 (2): 95-98, 2006

Composition and properties of fibre extracted from pseudostem of banana (*Musa sp.*)

S. Shivashankar, R. P. Nachane[1] and S. Kalpana[2]
Division of Plant Physiology and Biochemistry
Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bangalore - 560089, India
E-mail: siva@iihr.ernet.in

ABSTRACT

Pseudostem waste from five commercial cultivars of banana was used to extract fibre in order to study its properties. Fibre was extracted by decortification of sheath either manually or using Raspador machine. Yield of fibre in cultivars varied from 0.548% to 0.891%. There was no significant difference in the yield of fibre from different layers of sheath although differences among cultivars were significant. Cellulose was the major component of the fibre at about 60% while lignin levels were nearly 20%. The strength characteristics of Nendran fibre like, mean breaking load, mean breaking extension and tenacity were comparable to those reported for other naturally occurring plant fibres such as pineapple, jute and sisal. The study highlighted the importance of exploiting banana pseudostem after harvest of banana bunch for fibre production on a commercial scale.

Key words: Banana cultivars, pseudostem fibre, mechanical properties

INTRODUCTION

India is the largest producer of banana in the world. It is estimated that 1.5 million tonnes of banana fibre could be potentially extracted from 30 million tonnes of pseudostem waste produced annually each year across the country. The value of banana as a source of fibre has remained grossly underexploited due to lack of systematic research on structural and physical properties of its fibre. As the banana is cultivated round the year, it can provide uninterrupted flow of raw material for industry for production of a range of products like paper, cardboard, tea bags, fibre lining for car interiors, high quality dress material, currency notes, etc. Being natural and completely biodegradable, products developed from banana fibre can be expected to be in great demand in the international market. Keeping these points in view, the present work was initiated to study the properties of banana fibre extracted from different varieties under commercial cultivationd, and the results are presented.

MATERIAL AND METHODS

Biomass generation and composition of pseudostem fibre

Total biomass waste generated and yield of fibre from five commercial varieties of banana, viz., Poovan Nendran, Rasthali, Karpuravalli and Robusta were determined by destructive analysis upon harvest of bunch. Cellulose in the sheath and fibre was converted into acetylated cellodextrins by acetolysis with acetic/nitric reagent (4:1) followed by acid hydrolysis into glucose and was estimated following Sadasivam and Manickam (1996). Lignin was determined gravimetrically (AOAC, 1975).

Extraction of fibre

Fibre was extracted from the pseudostem using manual extractor or semi-automatic machine, Raspador, having a drum speed of 700-800 rpm. Fibres were freed from non-fibrous material by two methods, namely anaerobic retting and enzymatic retting. In anaerobic retting, fibres were tied at one end and suspended in a drum containing standard slurry (CIRCOT, 2003) containing more than one microbe type for two days to undergo degradation. The fibres were then removed, washed thoroughly under running tap water and dried in air. The strands of lustrous fibre with pale grey colour were separated out and stored for analysis.

Retting of fibre

Enzymatic retting of fibre was done with two sets of enzymes as described earlier (CIRCOT, 2004) In the first set, the fibre was incubated with the enzyme mixture containing Pulpzyme and Alcalase in a buffered medium at pH of 8.0 for 2 h at 50°C. One ml each of both the enzymes was added to 5g of sample, maintaining the fibre to liquor ratio at 1:25. At the end of incubation period, enzyme

[1] Central Institute for Research on Cotton Technology, Matunga, Mumbai - 400 019.
[2] National Research Centre for Banana, Thogamalai Main Road, Thayanur Post, Podavur, Trichy - 620 102.

activity was arrested by transferring the fibres to boiling water bath for 10 min. The fibre was washed thoroughly with water and dried (Method A). In the second set, retting was carried out at a pH 5.0 using a mixture of three enzymes, namely Aquazyme, Pectinex and Cellulase. One ml each of Aquazyme and Pectinex and 0.1ml of Cellulase were added to 5g of sample and the fibre to liquor ratio was maintained at 1:25. Incubation of the fibre was done at 55°C for 2 h. The fibre was washed with excess water and dried in air (Method B).

Testing tensile properties

Measurement on single fibre

Tensile tests were carried out on anaerobically retted as well as enzymatically retted fibres as described earlier (CIRCOT, 1999). The Instron Tensile Tester (Model 1122) was employed to carry out the tests. The gauge length used was 50 mm. The crosshead speed was adjusted such that the fibres split in 20-25 sec. About 50 strands of fibre were randomly chosen irrespective of thickness. These were individually mounted between the jaws of Instron tensile tester. Distance between jaws was adjusted to 50 mm, which was the gauge length of the fibres tested. One of the jaws was stationary, while, the other jaw moved at a speed of 5 mm/min. Extension of fibre was carried out till fibre ruptured. The load developed and corresponding extension at the point of rupture were recorded as the breaking load and breaking extension respectively, using dedicated computer software. Then, fibre pieces held in the two jaws were cut out at the jaws and collected. Weight of all the fibre pieces so collected was measured. Since each fibre was of 50 mm length and 50 such fibres were collected, the weight measured corresponded to fibres of 2500 mm or 2.5 m total length. From this value, weight of 1000m length of fibre, expressed in grams was calculated and expressed as tex of fibre. Tex is a measure of linear density of fibres. Tenacity, which is a measure of material strength, is defined as the ratio of breaking load by linear density expressed in tex. Accordingly, average tenacity of fibres was determined**.** The mean and CV (%) for all these parameters were worked out. The broken bits were placed between two glass slides and viewed under a projection microscope (magnification 500 X) for measuring diameter.

Measurements on fibre bundles

Bundle tenacity was measured at 3.2 mm gauge length using Uster Stelometer employing standard procedure as described below. A parallelised bundle of about 15 to 20 fibres was clamped in the stelometer jaws with a spacer of 0.32 mm (1/8th of an inch). This bundle was then tested on the stelometer for strength. Maximum load developed in breaking the bundle was measured. Six bundles per sample were tested. Weight of each bundle broken on the stelometer was measured. From the values of breaking load of bundle and its weight, tenacity of the fibre was calculated.

RESULTS AND DISCUSSION

Data on biomass production and fibre yield in five commercial cultivars of banana (Table 1) showed that the quantum of biomass left over after harves of bunch varied from 32.75 t/ha in ‘Rasthali’ to 38.61t/ha in ‘Karpuravalli’. Of this, about 40% of pseudostem sheath comprising the outer 3-4 layers could be utilized to extract the fibre. The outer sheath is composed of tightly covered layers of fibre. Among the cultivars tested, the variety Poovan gave maximum fibre yield of 0.891%, while, ‘Karpooravalli’ registered the lowest at 0.548%. Fibre content of the outermost three layers of pseudostem sheath did not differ significantly, but, the yield of extractable fibre was significantly different among varieties (Table 1). The total quantum of fibre production in these cultivars varied from a low of 15.8 kg/ ha in ‘Karpuravalli’ to a high of 32.7 kg/ ha in ‘Poovan’ showing, thereby, that it is possible to exploit the pseudostem of all these commercial cultivars for production of fibre, these cultivars being cultivated extensively in different parts of India.

Banana pseudostem contained 93.2-94.6% moisture. There were significant differences in potassium

Table 1. Biomass generation and fibre yield in commercial cultivars of banana

Commercial cultivar	Biomass after bunch harvest(t/ha)	Whole plant weight (kg)	Pseudostem weight (kg/plant)	Fibre extractable sheath weight (kg/plant)	Fibre yield (%)
Poovan	37.12	20.4	14.0	8.06	0.891
Nendran	36.48	20.1	13.2	7.62	0.758
Rasthali	32.75	18.0	13.1	5.88	0.697
Karpuravalli	38.61	21.1	13.5	8.13	0.548
Robusta	36.01	21.4	14.0	8.40	0.721
C.D (*P*=0.05**)**	1.342	0.992	0.314	0.406	0.001

Table 2. Composition of pseudostem in commercial cultivars of banana

Commercial cultivar	Moisture (%)	pH	Acidity (%)	Sodium (mg %)	Potassium (mg %)
Poovan	93.4	6.21	0.018	0.20	7.33
Nendran	94.6	6.19	0.019	0.30	6.06
Rasthali	93.2	6.37	0.017	0.75	5.33
Karpuravalli	94.6	6.69	0.017	0.35	6.76
Robusta	94.1	5.85	0.016	0.50	6.15
C.D (*P*=0.05)	NS	0.0156	0.005	0.022	0.120

and sodium levels among the cultivars (Table 2). High moisture content of the fresh pseudostem actually favoured fibre extraction, and, both the yield and quality of fibre decreased with decrease in the moisture level in the pseudostem during storage. The juice extracted by crushing the sheath was slightly acidic showing significant differences in pH ranging from 5.85-6.69 and acidity values of 0.016-0.019%. pH values ranging from neutral to slightly alkaline are known to be ideal for obtaining fibre of high quality and durability. Sikdar *et al* (1993) reported that slightly alkaline pH of plant sap helped dissolve non-cellulosic matter resulting in better fibre quality in jute. Due to the slightly acidic pH of banana pseudostem, pre–treatment with dilute alkali was necessary to obtain high quality fibre as shown in sisal by Padmavathy and Venkata Naidu (1998). Acidic pH of abaca (*Musa textiles)*) pseudostem was shown to reduce the strength and durability of its fibre (Kirby, 1963).

Lignin content of different varieties did not show significant variation although it ranged from 18.55% in 'Poovan' to 22.46% in 'Rasthali'. These results showed that banana fibre is more lignified than other soft fibres such as flax, ramie, jute and hemp (Kirby, 1963). Banana fibre is known to belong to the group of leaf fibres which are in general coarser than bast fibres. Cellulose content in banana sheath among accessions belonging to different genomic groups was found to differ significantly (Table 3). AAB group had mean cellulose content of 22%, while, it was 27.2% in AB, 26.5% in AAA, 28% in BB and 26% in ABB groups. The cellulose content of fibre in commercial varieties also varied significantly, from a low of 53.17% in 'Poovan', to a high of 66.57% in 'Nendran' (Table 3), similar to those reported in jute (60.7%) and mesta (61.6%). Cotton fibre is reported to have the highest cellulose content (82.7%), followed by ramie (68.6%), hemp (67.0%) and sisal (65.8%). The cellulose/ lignin content (%) obtained in this study were also found to be similar to that reported for jute, sisal and pineapple fibres (Al Qureshi, 1999).

Table 3. Cellulose and lignin content in commercial cultivars of banana

Commercial cultivar	Lignin content (%)	Cellulose content(%)
Poovan	18.33	53.17
Nendran	20.80	66.57
Rasthali	22.40	62.83
Karpuravalli	22.03	65.00
Robusta	20.23	56.83
C.D **(** *P*= 0.05 **)**	NS	1.56

Several studies on fibre composition and morphology have revealed that cellulose content and microfibril angle tend to control mechanical properties of cellulosic fibres (Biswas *et al*, 2001). Cellulose is a natural polymer with high strength and stiffness per unit weight and is the building material of long fibrous cells. Higher cellulose content and lower microfibrilar angle lead to higher work of fracture in impact testing. Being cellulose-rich, banana fibre is reported to compare favourably with fibres of jute and flax in tensile strength, modulus and failure strain (Biswas *et al*, 2001).

Data on strength characteristics of banana fibre extracted from cv. Nendran are presented in (Table 4) and relate to measurements made on single fibre. Significant differences were observed in the tenacity of fibre obtained by anaerobic and enzymatic retting methods. Other parameters of fibre too differed significantly among fibres extracted by different methods thereby, showing that, anaerobically retted fibre was superior to the enzymatically retted fibre. The bundle tenacity of anaerobically retted fibres showed values of 4.098 kg for breaking load, 2.425% for breaking extension, 1.812 mg for weight of tuft with a tenacity of 34.35 g/tex. The values of tenacity obtained in this study matched favourably with those reported earlier on some cultivars of banana grown in the Philippines. It has been reported that the quality of matrix composed mainly of lignin and hemicellulose exerts a strong influence on tenacity (Mukherjee and Satyanarayana, 1986).

Results from the present study show that mechanical properties of the fibre extracted from pseudostem of variety Nendran of banana compare favourably with that of other natural fibres like that of pineapple, sisal and jute. It may be inferred that fibre from different varieties of banana is also likely to behave similarly

Table 4. Mechanical properties of single fibre of cv. Nendran

Method of fibre extraction	Mean breaking load (kg)	Mean breaking extension (%)	Mean diameter (mm)	Tex	Tenacity (g/tex)
Anaerobic retting	0.282	2.772	0.110	4.636	60.828
Enzymatic retting (Method A)	0.281	2.464	0.166	7.984	35.195
Enzymatic retting (Method B)	0.160	1.818	0.114	4.398	36.380
C.D **(** P=0.05**)**	0.008	0.038	0.008	0.675	1.887

and the extent of differences, if any, could vary depending upon its cellulose and lignin content. Thus, variations in cellulose and lignin content among cultivars, which are determinants of fibre quality, could be of value in assigning fibre to specific end uses.

It follows, therefore, that it is possible to utilize banana fibre profitably for preparation of several value-added byproducts. Although, traditionally, banana fibre has been used for making ropes, cords and packaging material, it can also be used as reinforcement in polymer composites, replacing more expensive and non-renewable synthetic fibres such as glass. These composites can be a cost effective material for the building and construction industry, for packaging, automobiles, railway coach interiors and storage devices. The use of banana cellulosic fibre in its native condition for reinforcement of different thermoplastic and thermonetting materials like phenol-formaldehyde, unsaturated polyester, epoxy, polyethylene, cement, natural rubber, etc., has also been reported. Banana fibre shows better reinforcing efficiency than coir and specific strength properties of the composites are comparable to those of glass-fibre reinforced plastics (Al Qureshi, 1999). Due to the high cost of synthetic fibres like glass, carbon or plastics used in fibre –reinforced composites and the health hazards caused by asbestos fibres, it is important to explore natural fibres like that of banana as possible substitutes. More detailed studies on the properties of banana fibre would help find many value-added applications which could directly contribute to better utilisation of banana pseudostem which would be otherwise wasted.

ACKNOWLEDGEMENTS

The authors wish to thank the Director, NRC for Banana, Trichy, for providing facilities. Encouragement and support provided by the Director, IIHR, Bangalore, is gratefully acknowledged.

REFERENCES

Al Qureshi, H.A. 1999. The use of banana fibre reinforced composites for the development of a truck body. In: *Proc. 2nd International Wood and Natural Fibre Composites Symp.* June 28-29, 1999, Kassel, Germany.

AOAC 1975. Official Methods of Analysis (1975), 12th ed. p. 138.

Biswas, S., Srikanth, G and Sangeeta Nangia. 2001. Development of natural fibre composites in India. In: *Proc. Ann. Convention & Trade Show*, COMPOSITES 2001, held at Composites Fabricators' Association, Tampa, Florida, USA , 3-6 Oct, 2001.

CIRCOT 1999. Tensile Properties of Fibres, An Insight Into Ligno-Cellulosic Fibres - Structure and Properties, Technical bulletin Published by the Central Institute for Research on Cotton Technology, Matunga, Mumbai 400 019, India, pp.11-24.

CIRCOT 2003. Annual Report. Physicochemical and Structural Characteristics of Banana Pseudostem Fibre, CIRCOT Annual Report 2002-03, Published by the Director, Central Institute for Research on Cotton technology, Matunga, Mumbai 400 019, India, p.42.

CIRCOT 2004. Annual Report. Physicochemical and Structural Characteristics of Banana Pseudostem Fibre, CIRCOT Annual Report 2003-04, Published by the Director, Central Institute for Research on Cotton technology, Matunga, Mumbai 400 019, India, p. 53.

Kirby, R.H.1963. Vegetable fibres: World Crop Series. Leonard Hill, London, and Interscience, New York, USA.

Mukherjee, P.S. and Satyanarayana, K.G. 1986. An empirical evaluation of structure-property relationships in natural fibres and their fracture behaviour. *J. Materials Sci.,* **21** : 4162-4168.

Padmavathy, T. and Venkata Naidu,S. 1998. Chemical resistance and tensile properties of sisal fibres. *Ind. J. Fibre and Textile Res.,* **23 :** 128-129.

Sadasivam, S. and Manickam. A. 1996. Biochemical Methods. Second Edition, New Age International Publishers, p.13.

Sikdar,B., Mukhopadhyay, A.K. and Mitra, B.C. 1993. Action of weak alkali on jute. *Ind. J. Fibre and Textile Res.,* **18 :** 139-144.

(MS Received 22 May 2006, Revised 16 October 2006)