Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

Comparative analysis of fibres from six different cultivars of banana

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ABSTRACT

Bananas are major food crops, grown globally and consumed by people from over hundred countries throughout the tropics and subtropics. The value of banana as a source of fibre has remained grossly under exploited due to lack of systematic research on structural and physical properties of its fibre. After harvesting the fruits of Banana, the pseudo stems are usually thrown away as waste. However, pseudo stems and peduncle are rich sources of fibre. Realizing their importance, banana fibres are being used in many of the industries for making useful products like ropes, cordage, paper, bags, handicrafts and also in the preparation of reinforced composites.Being natural and completely biodegradable, products developed from banana fibre can be expected to be in great demand in the international market. The present work deals with the comparison of physical, chemical and mechanical properties of six culivars of banana *viz*, Nendran, Karpooravalli, Red banana, Robusta, Neypoovan and Palayamkodan.

KEYWORDS: Banana fibre, Extraction , Quality analysis, Tensile strength.

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INTRODUCTION

Banana (*Musa* spp.)belongs to the family Scitamineae, sub-family Musaceae is native to Southeast Asia. *Musa* includes about 1000 varieties of bananas in the world and all known members of the genus are considered to be derived from the two wild species, *M. acuminata* (AA) and *M. balbisiana*(BB). Human beingsutilize the flowers, fruits and psuedostem as food. Banana pseudo stem has other applications also. The bastfibres extracted from the pseudo stem as well as the leaf sheath is considered to be superior in quality.Certain species such as *M. textilis* are well known for their strong and sturdy fibres and are being grown especially for their fibres. Wild species like *M.balbisiana*var. cola, *M. balbisiana* var. *And amanica*existing in Andaman and Nicobar Islands are also used for commercial extraction of fibres just as flax, jute, kenaf, hemp, ramie and rattan[1,2]. The banana bast fibres having higher tensile strength, is used for the production of durable yarn, fabric, and packaging materials. Of late, due to advancements in fibre reprocessing technologies, banana fibres have found many applications. They are being utilized for the manufacture of paper, currency, ropes, cordages, gunny bags and other handicrafts.

MATERIALS AND METHODS

Six different cultivars of *Musa* namely Karpuravalli, Nendran, Red Banana, Robusta, Palayamkodan, Neypoovan were used in this study (Table1.).Fresh and healthy pseudo stems of these cultivars were collected from Kollam district, Kerala, India.

Table 1.List of *Musa* cultivars presently studied and their genomic constitution

Sl.No.	Name of the Taxa	Genomic group
1	*Musa ×paradisiaca L. 'Karpuravalli'*	ABB
2	*Musa × paradisiaca L.'Nendran'*	AAB
3	*Musa acuminate Colla. 'Robusta'*	AAA
4	*Musa acuminate Colla. 'Red banana'*	
5	*Musa ×paradisiaca L.'Palayamkodan'*	AAB
6	*Musa × paradisiaca L.'Neypoovan'*	AB

Extraction of Fibre

Fibres were extracted from the stems of *Musa* using the water retting method. The stem samples weighing about 500g were cut into pieces of about 20-30 cm long and then put within large vessels filled with water. The water within the container was changed every day for about 30 days. Retting was allowed to proceed for nearly one month. The fibre so obtained was washed, dried and stored.

The physical properties of fibres such as fibre yield, fibre dimension, fibre density, ash content and water holding capacity were determined.

Fibre yield analysis

The quantity of fibre obtained from a fixed quantity of stem pieces (500g) was weighed to determine the fibre yield.

Fibre density measurement[3]

The specimens were conditioned for 24 hrs at 65% relative humidity & 25^0 C prior to the test.About 0.5g sample was weighed out for each fibre type. Each fibre was immersed in toluene in a calibrated glass tube and the value of toluene displaced was determined and considered equal to the volume of fibre immersed. The density of the fibre was calculated from the formula

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Ash content test

About 2g of fibre sample was weighed into a pre weighed porcelain crucible and kept in muffle furnace set at 550^0C for 4 hours. Later, the crucible and its content were cooled down and weighed.

$$\%\text{ of ash content} = \frac{\text{Weight of crucible with sample} - \text{Weight of crucible}}{\text{Original weight of sample}} \times 100$$

Water holding capacity[4]

The water retention value (WRV) was calculated as shown in the equation below

$$\text{WRV} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} \times 100$$

SEM analysis

The surface morphology and dimension of fibres were determined by SEM, ZEISS EVO 18 USA. The specimens were coated with a thin gold–palladium layer using Sputter Coater to avoid electrical charge accumulation during examination.

Estimation of Cellulose, Hemicellulose and Lignin[5]

About 2g of fibre samples were boiled in ethanol (four times) for 15 minutes and washed with distilled water and kept overnight in oven at 40^0Cfor estimating the dry weight. Then it is divided into two parts. One part is considered as 'A' fraction. Second part of residue was treated with

24% KOH for 4 hrs at 25^0C, washed thoroughly with distilled water, dried at 80^0C overnight and the dry weight taken as 'B' fraction. The same sample is again treated with 72 % H_2SO_4 for 3 hrs to hydrolyse the cellulose and then refluxed with 5% H_2SO_4 for 2 hours. $H_2SO_4$was removedcompletelyby washing with distilled water, dried at 80^0 C in an oven overnight and dry weight taken as 'C' fraction.

Cellulose = B-C

Hemicellulose = A-B

Lignin = C

Estimation of Fatty and Waxy matter

The raw fibre was immersed in benzene - alcohol mixture (2:1) by volume for 10 hrs maintaining the fiber liquor ratio as (1:100). The fibre was washed with fresh benzene - alcohol mixture and finally with alcohol. The amount of fatty and waxy matters present in the fibre was calculated by loss in weight.

Estimation of Pectin

The dewaxed fibre was heated with 0.5 % ammonium oxalate solution at 70-80^0C for 72 hrs in a heating mantle. Then the fibre was filtered, washed thoroughly with hot distilled water. The amount of pectin present in the fibre sample was determined by the loss in weight.

Mechanical Properties of Fibre

The tensile properties of fibres in terms of mean breaking strength, mean breaking elongation, fibre fineness, tenacity and Young's modulus were determined using tensile testing machine Zwick/Roell Z005 (Model) from SITRA Coimbatore. The tests were carried out according to the standard protocol ASTM D 3822 with gauge length 20 mm and test speed 18 mm/minute.For calculating the tensile properties, fibre samples of equal length was prepared. About 30 fibres of each sample were tested and their mean value is taken.

RESULTS

In the present study the physical properties of fibers such as yield, density, ash content and water holding capacity were analyzed (Table-2). The fiber yield for the six cultivars showed significant variations. The highest percent yield was obtained from pseudo stem of Karpuravalli (1.76%) followed by Robusta (1.59%) and Nendran (1.53%) while that from Neypoovan was the least (1.14%).The fibres of Robusta (0.083g/ml) and Neypoovan (0.082g/ml) showed higher density compared to the other four varieties, which exhibited almost similar values. Among the six cultivars, highest ash value was seen in Karpuravalli (2.83) and lowest in Palayamkodan (1.54). Nendran and Red banana had comparable values with that of Karpuravalli. The highest WRV was found for Karpuravalli, followed by Neypoovan. There were no significant differences in the WRV, for all cultivars under study (79.71-74.33 %).

Table 2.Physical properties of fibres from different banana cultivars

Sl.No.	Name of the plant	Yield (%)	Density (g/ml)	Ash Content (g)	Water holding capacity (WRV) %
1	Karpuravalli	1.76±0.005^{a}	0.063±0.0005^{e}	2.83±0.05^{a}	79.71±0.005^{a}
2	Nendran	1.53±0.005^{c}	0.065±0.0005^{d}	2.74±0.005^{b}	75.35±0.005^{c}
3	Robusta	1.59±0.005^{b}	0.083±0.0005^{a}	2.36±0.05^{c}	74.33±0.005^{f}
4	Red banana	1.24±0.005^{e}	0.069±0.0005^{c}	2.69±0.005^{b}	75.29±0.005^{d}
5	Palayamkodan	1.32±0.01^{d}	0.062±0.001^{f}	1.54±0.01^{e}	75.25±0.005^{e}
6	Neypoovan	1.14±0.005^{f}	0.082±0.00^{b}	1.89±0.005^{d}	77.27±0.005^{b}

Values in the table is represented as mean ±SD (n=3) Means not sharing the same letter are significantly Different (LSD) at P< 0.01 probability level in each column.

SEM PHOTOGRAPHS OF MUSA CULTIVARS

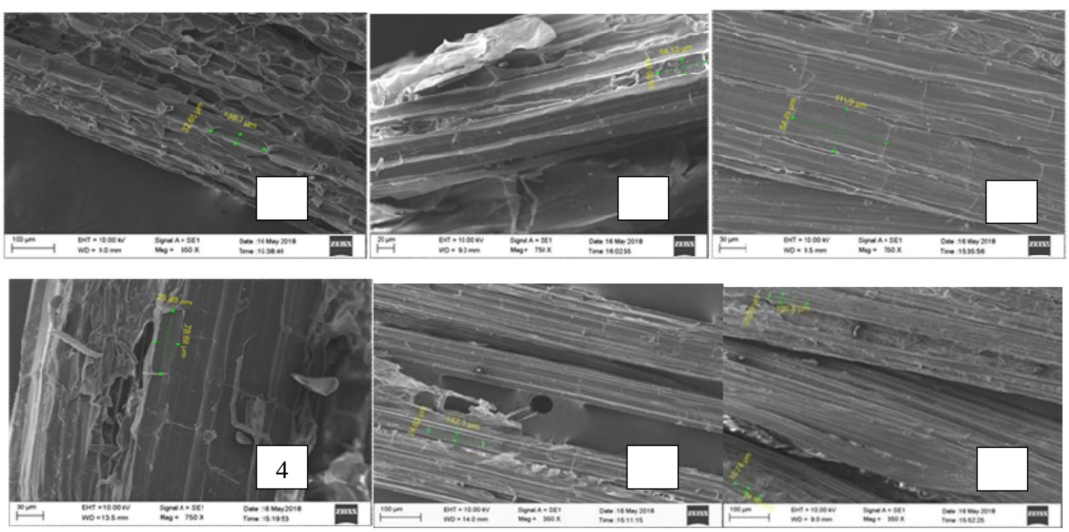

Fig. 1- Karpuravalli fibre, 2- Nendran fibre, 3- Robusta fibre, 4- Red banana fibre, 5- Palayamkodan fibre, 6- Neypoovan fibre.

Chemical components *viz.*, cellulose, hemicelluloses, lignin, pectin, fatty and waxy matter were evaluated among six cultivars**(**Table-3). Karpuravalli showed highest cellulose content (66.56%) followed by Nendran 60.43% while the lowest value was observed in Palayamkodan (52%). In the present study, highest percent of hemicellulose content was observed in Nendran fibres (15.90%) and lowest in Red Banana (12.09%). The highest percent of lignin was observed in

Nendran (17.11%) and lowest in Robusta (12.13%).The fatty waxymatter and pectin content was almost negligible in the pseudostem of banana.

Table 3. Chemical composition of fibres from different cultivars of *Musa*

Sl.No.	Name of the plant	Cellulose (%)	Hemicelluloses (%)	Lignin (%)	Fatty &Waxy matter (%)	Pectin (%)
1	Karpuravalli	66.56±0.005^{a}	12.64±0.005^{d}	16.70±0.005^{b}	1.007±0.0005^{f}	0.99±0.0005^{a}
2	Nendran	60.43±0.005^{b}	15.90±0.005^{a}	17.11±0.01^{a}	1.03±0.0005^{c}	0.97±0.0005^{c}
3	Robusta	56.82±0.005^{c}	15.69±0.005^{b}	12.13±0.005^{f}	1.14±0.0005^{b}	0.96±0.0005^{d}
4	Red banana	54.11±0.005^{d}	12.09±0.000^{f}	14.38±0.005^{c}	1.34±0.0005^{a}	0.96±0.00^{e}
5	Palayamkodan	52±0.00^{f}	12.21±0.00^{e}	13.39±0.005^{f}	1.03±0.0005^{d}	0.99±0.006^{b}
6	Neypoovan	53.16±0.005^{e}	14.19±0.005^{c}	12.35±0.005^{e}	1.01±0.0005^{e}	0.90±0.0005^{f}

Values in the table is represented as mean ±SD (n=3) Means not sharing the same letter are significantly different (LSD) at P< 0.01 probability level in each column.

The fibre from Karpuravalli exhibited highest tensile strength with Young's modulus value of 204.19MPa. The mean breaking strength, fibre fineness, tenacity and Young's modulus of six cultivars were recorded (Table - 4).

Table 4. Tensile properties of the fibres from *Musa* cultivars

Features	Karpuravalli	Nendran	Robusta	Red banana	Palayamkodan	Neypoovan
Mean Breaking Strength Fmax (N)	4.50±3.32^{b}	4.61±1.53^{b}	4.46±1.80^{b}	4.45±1.41^{b}	6.10±3.69^{a}	2.33±0.86^{c}
Mean breaking elongation (%)	1.63±0.57^{c}	2.15±0.61^{a}	1.76±0.55^{bc}	2.01±0.43^{ab}	1.88±0.69^{abc}	1.75±0.55^{bc}
Tenacity (gram force/ tex)	1.96±1.44^{c}	5.23±1.73^{a}	4.16±1.67^{b}	4.89±1.55^{ab}	5.00±3.02^{ab}	2.08±0.77^{c}
Young's modulus Emod (mpa)	204.19±96.26^{a}	143.28±43.89^{c}	166.07±40.66^{bc}	165.87±45.04^{bc}	197.08±76.23^{ab}	100.61±36.34^{d}
Fibre fineness (denier) Cut & weigh method	234.0	90.0	109.5	92.9	124.5	113.9

DISCUSSION

In the present study, fibres were extracted from six cultivars of banana over a period of 30 days by the water retting method. This method relies on the microbial degradation of pectin polysaccharides from the bast[4,6]. Fibre density plays a direct role in affecting the fabric weight and is considered to be a useful parameter in fibre identification. Thus Palyamkodan and Karpuravalli having lowest density can be utilised for making fabric. The fibre density depends upon various factors such as the process of fibre extraction, age of the plant and soil condition in which the plant has grown[7].Ash of banana fibres was found to have good binding properties, low density, appropriate stiffness and high disposability so that it could be a substitute for high quality cement[8].

The water retention capacity of fibres is mainly defined by its supermolecular structure and the structure of voids, which are the driving force for water absorption in cellulose fibres[9]. Water retention value (WRV) is a useful reference to evaluate the performance of cellulosic materials, relative to moisture behaviour.

Scanning electron microscopic (SEM) provides an excellent exposition of the surface morphology of banana fibres. The main quality parameter of raw textile material is fibre length because length to width ratio is the primary requirement of any textile fibre. It is clear from SEM images of the banana fibres that they contain bundles of individual cells that have been bounded together by lignin.

The physical and mechanical properties of natural fibres are greatly influenced by the chemical composition. Fibre source, the extraction process, and the age determine fibre composition[10].Cellulose molecules occur as long thin crystalline micro-fibrils and are the reinforcing material in the secondary cell wall,which provide quality and mechanical strength to the fibre[11]. The pseudostem of banana fibre from Karpuravalli and Nendran exhibited 60-66% cellulose which was similar to the earlier report[12]. Higher cellulose content contributes to the higher mechanical strength of fibre, which makes it preferable for textile, paper and other applications[8,13]. Earlier reports were nearly similar for Nendran 59.22%[1], while a higher value was reported for Poovan (80%)[14]and lower value for *Musa sapientum* (31.27%)[8]. Hemicelluloses link the cellulose micro-fibrils together and upon degradation result in lower fibre bundle strength. In the present study, highest percent of hemicellulose content was observed in Nendran fibres. Lignin acts like a matrix material within thefibres, making stress transfer[15]and plays a crucial role in conducting water in plant stem. Lignin content of different cultivars did not showed any significant variation.A similar result was reported for Nendran in previous studies[16]. The fatty waxy matter and pectin content was almost negligible in the pseudostem of banana.

Tensile strength was observed to be highest in Karpuravalli fibre (Young’s modulus of 204.19 MPa). Strong fibres with high tensile strength are used in cordage industry, for the development of composites like particle boards and used for making baskets, ropes and handicrafts. Among the different cultivars studied more fine fibres were obtained from Karpuravalli.Tex is a measurement of linear density of fibres and decides the fibre fineness. Generally strength increases with increasing moisture content and decreases as temperature increases. The Young’s modulus is known to decrease with moisture content[17]. Tensile properties of fibres are highly influenced by the cellulose content. In the present study, higher cellulose content in Karpuravalli can be correlated with its higher tensile strength.

CONCLUSION

Results of the present investigation showed that among the six cultivars Karpuravalli bast fibre possessed distinct physical, chemical and mechanical properties. They had the hardest and stiffest fibres and also, the fibres were very short. High water retention value of Karpuravalli indicates the hydroscopic nature of the fibres. For these reasons, the fibres of Karpuravalli can find applications in cordage, paper and textile industries.

ACKNOWLEDGEMENT

Authors are thankful to Dr. Anil Kumar, Principal, and Dr. SudhaBai, Assistant Professor and Head, Department of Botany, University College Thiruvananthapuram for providing the necessary facilities for the conduct of this research work.

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