SCOPE OF BANANA AND PLANTAIN PSEUDOSTEM SHEATHS FOR FIBRE EXTRACTION AND ITS UTILIZATION

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled **"Scope of banana and plantain pseudostem sheaths for fibre extraction and its utilization"** is a bonafide record of research work done by me during the course of research work and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that the thesis entitled **Scope of banana and plantain pseudostem sheaths for fibre extraction and its utilization** is a record of research work done independently by **Mr. N. Gopinath** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

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N. Gopinath

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INTRODUCTION

I. INTRODUCTION

Banana, one of the earliest crops cultivated by man, still remains to be one of the most important fruit crops of the tropics. India has third place in world banana production and is cultivated extensively in a number of states of the country. Large number of cultivars are being grown in a wide range of soil and agro climatic conditions under different cropping and farming systems.

Banana plant with every part being useful to man in many aspects as food is a versatile plant. So it's known as "God's gift to mankind" (Rao, 1999). Banana has a lot of vistas for utilization apart from it is use as dessert fruit. Usually the fruits are used for table as well as culinary purposes, whereas other parts of the plant are being wasted. An efficient use of these wastes can help to maximise the income and minimise the pollution hazards (Maini, 1992).

Banana pseudostem is a source for fine quality fibre. The genus Ensete, Australian musa and Eumusa yield useful fibre. Musa gives an excellent fibre and it is used in garland making as well as for cloth making (Shanmugavelu *et al.*, 1992). Cultivated banana and plantain have very high potential as a natural source of fibre. Though raw material is available in plenty, only negligible quantity of the pseudostem is utilized for fibre extraction at present. The production of banana fibre is far less than the requirement and the demand is fast increasing (Yesuvadian, 1998). The fibre extraction and product preparation is confined mainly in Tamil Nadu and Kerala. More than 170 institutions are engaged in fibre industry in Kerala. The industry has enourmous scope for providing employment opportunity especially to women in developing countries.

Banana fibre has conventional and non-conventional uses. There is immense scope for utilizing banana fibre for large-scale production of carry bags instead of plastic bags now used which is creating environmental hazards throughout the world. Considering the importance of banana fibre, Khadi and

Village Industries Commission and Government of India are giving added important for its research, training and extension effort.

In the ever expanding materialistic world, serious and wide spread innovation in the extraction, processing and utilization of banana fibre are more and more important. There is real need emerging now making this eco friendly industry more popular and as an income generating employment avenue for rural masses.

Under this context an investigation on "Scope of banana and plantain pseudostem sheaths for fibre extraction and its utilization" was conducted with the following objectives:

1. To assess the suitability of banana and plantain pseudostem sheaths for extraction of fibre through different techniques and to evaluate quality of fibre so obtained.
2. To study the effect of different packages/containers and environment on the retention of quality of banana fibre during storage.
3. To test the feasibility and durability of plaited banana fibre and banana ropes.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Man has long used fibres from plant sources and there was increasing interest in the potential use of such fibres from non- tree sources (Mcdougall *et al.*, 1993).

Banana, the major fruit crop of Kerala is grown commercially as an annual crop in lands taken under annual lease. This practice necessitates the complete removal of the plants immediately after harvest. Large quantity of bio-waste is generated every year due to banana cultivation, which needs to be disposed off. This wasted pseudostem can be used as a source for fine quality fibre which was highly valued in the market for its durability and strength (Suma *et al.*, 2002).

2.1 METHOD OF EXTRACTION

2.1.1 Hand extraction

Banana fibre extracted by hand was preferred as best quality fibre. After harvest of bunch leaf sheaths were peeled from pseudostem. The sheaths were cut into length of 40cm to 60cm and split into pieces of 6cm to 10cm width. The flesh, juice etc were scraped by hand with the steel blade (6cm x 5cm) fitted with wooden handle and holding the sheath with other hand. A few forward movement of the blade unveiled the fibre (Pushkaran, 1996).

Gupta (1996) found that in the manual process of pineapple fibre extraction, the leaves were first decorticated by beating, rasping, stripping and then left to ret in water into which chemicals were added to accelerate the activity of micro organisms which digested the unwanted tissue and separated the fibres. The retted materials were washed, cleaned, dried in the sun and combed.

Ranjith (1998) found that the pineapple leaves could be cut to gain the fibre and stated that in leaves the epidermis was removed with the piece of bamboo to expose the pina fibre and then the fibre was spun together with silk to form a shiny thread.

Iyer *et al.*, (1998) observed that among the fibres extracted from cultivars Nendran, Ney Poovan, Dwarf Cavendish and Giant Cavendish respectively, the fibre yield was the highest from Nendran (471 g per plant) under hand extraction.

Hewawasama (2000) studied the effect of hand extractor in the extraction of abaca fibre and reported that tuxies (leaf stem) pulled under a knife that was pressed against a block of wood by means of a bamboo spring removed the pulp and other waste material leaving the cleaned fibre in the hands of the operator.

FIDA (2000) reported that hand stripping was the most commonly used method for abaca fibre extraction in which pressure was applied on knife and then fibre was extracted by pulling the tuxy (leaf stem) manually.

Nachane and Uma (2001) reported that banana pseudostems possessed good quality fibres from one to three per cent by weight. He also found that skilled person could extract at the most 100 to 150 g of dry weight fibres per day.

Nair (2004) reported that 12 to 14 banana pseudostems produced one kg of fibre under conventional method of hand extraction.

2.1.2 Extraction by machine

After the fruits were harvested, fibre was extracted from pineapple leaves by mechanical process which yielded two per cent of the weight of the leaves and the fibre was very soft, fine with lustrous appearance (KVIC, 1998).

Based on detailed studies on pineapple leaf scrapping machine Paul *et al.* (1998) reported that a small scrapping roller of diameter 87 mm, width 125 mm and 27 scrapping blades, scarp the leaves at adjusting angles. The prolonged scrapping action produced large quantity of fibres. Zhang-zing (2000) reported that pineapple fibre under mechanical method of extraction underwent pulping and vibration before the sediment was separated and two sets of equipments in the machine exhibited good performance in quality and quantity.

Banana plants were cut down as soon as fruits were harvested for extraction of fibre. Stems and ribs of leaves contained a very good quality fibre of considerable length. Out of 20 to 25 sheaths available in a stem the outer four to six sheaths yielded coarse fibre, the inner six to eight sheaths yielded soft lustrous fibre and the rest yielded very tender fibre (Sinha, 2000).

The fibre extraction machine Raspador produced 5 kg of good quality (less rigidity, silky) dry weight banana fibre per day at a shift of eight hours and had same mechanical properties as observed in hand extracted fibres (Nachane and Uma, 2001).

Sudhakar (2002) reported that banana fibre extractor produced 25 kg of fibre per day against 500 g of fibre production through manual operation. The quality of fibre in terms of length, softness, strength and colour was superior under this method.

Ramy-azer (2002) reported that long fibre technology was a best way to convert banana pseudostems to fibres. He stated that long fibre technology needed no water, no chemical and less energy compared to traditional technology that pulped the fibre to a very small size with the help of water and lot of energy.

Margretfrey (2003) reported that electro spinning technique produced high strength and quality fibre at low cost from cellulose rich stems like banana and sisal.

Venkatasubramanian (2003) found that a low cost banana fibre extractor extracted 15 to 20 kg in a day compared to 500 g a day through laborious manual process. The machine extracted fibre was superior quality in terms of length, softness, strength and colour that was used for making good quality paper and for blending in textile industry. Kalpana (2003) reported that extraction of banana fibre by hand extraction was an arduous task and could extract just 500g per day, whereas in mechanical process the same quantity could be extracted in an hour.

2.1.3 Extraction by retting

Retting is the process of soaking or immersing the vegetable matter in tanks, pits, ponds, and stagnant water o in acids and alkalies and microbial culture.

Ganguly (1992) conducted studies on microbial retting of jute and found that spraying of water for first three days on harvested stems and covering with plastic film for fermentation produced fibres of quality equal to quality of fibre retted by other methods. Similar studies by Liu-Zhengchu (1995) found that retting time was decreased to 40 per cent by an addition of 0.1 per cent of green stem of urea to the retting water.

Meijer *et al.* (1995) found that water retting degraded the pectin content of flax fibre from 25 to 30 g per kg to 7 to 10 g per kg within 6 days. Lancon (1998) reported that when plant stems were placed in water and allowed to rot the thick walled xylem remained with it that was removed by scutching and drawing hackled the fibres across a comb.

Heinmann (1995) found that retting had no effect on mechanical stability of fibre but yield, fineness and degree of delignification was largely acceptable with some difference in fibre colour and texture. On comparing the fibre character under retting Pallensen (1996) observed that flax straw with ammonia improved fibre quality with high degree of purity and fibre strength.

Cang (1998) reported that extraction of abaca fibre with aqueous one per cent sodium hydroxide removed the hemi cellulose fraction strongly enriched with xylose containing polysaccharides within five days.

After harvesting, banana stem were steeped in water for retting. The period of retting varied from six to ten days depending on the maturity. The extraction of fibre was done by mechanical decorticator. The output per day was more but had disadvantages like reduced length of fibre and more wastage (Chand and Hasmi, 2000).

Law (2001) reported that use of sodium hydroxide in combination with sodium sulphite in musa fibre extraction showed excellent mechanical properties and a great potential as a reinforcement component in newsprint making.

Akin (2001) in his study on enzyme retting of flax and characterization of processed fibres found that an enzyme Viscozyme L at 0.3 per cent with 25 mm EDTA produced best short staple flax fibres. Similar study on analysis of retted and non - retted flax fibres by chemical and enzymatic means, Mooney (2001) found that retting caused minimal weight loss from the fibre and significant change in the amount of rhamnogalacturon as well as arabinon and xylan.

Among various fungi tested for retting efficacy on green jute ribbons Shamsul *et al.* (2001) found that *Trichoderma* spp. retted green ribbons in 11 days with the yield of about 2.8 kg out of 40 kg green ribbons.

Koster *et al.* (2001) stated that chelators with pectinase enzyme mixtures increased the efficiency of enzyme retting of flax. EDTA was the most effective chelator at idic pH for stimulating flax retting. Similar studies by Sulaiman (2001) found that among the retting trials chemical retting at high pH with EDTA or Sodium tri polyphosphate gave fine fibre yield.

2.2 Properties of fibres

The quality of abaca fibre was determined by the part of stalk from which fibres was obtained. The outer sheath of abaca stalk produced short strong and discolored fibres, middle sheath produced fibre of medium colour and good strength. The sheath near the center produced fibre of medium strength and very white colour (Hewawasama, 2000). Guo *et al.* (1994) reported that fineness of fibre was higher in the middle of the plant than at the top or base.

Bhattacharya (2000) reported that during the process of cleaning of abaca fibre, use of coarsely serrated stripping knife resulted in production of coarse and low-grade fibre. Delay and carelessness in drying affected both the colour and strength of fibre (Mukherjee, 2000).

Jeyachandran *et al.* (2000) found that exceptional strength of abaca fibre and its quality of resistant to the action of saltwater made abaca fibre particularly suitable for marine cordage.

Based on detailed study on physiochemical properties of abaca fibre Satinder *et al.* (1993) reported that using of chemicals like hydrochloric acid, formic acid, sodium hydroxide caused swelling of fibres and reduced the quality, whereas, when treated with water produced fibres of longititudinal striations and rounded ends.

Lenz (1994) reported that tensile strength and extensibility were the most important mechanical properties of fibres. Biswas (2001) reported that banana fibres are cellulose rich with high tensile strength and modulus compared with other cellulose rich fibres like jute and flax.

In the preliminary study on relationship between stem shape, fibre yield and fibre fineness in abaca, Zhou *et al.* (1992) found that thickness of stem was positively correlated with fibre cell number.

Based on the studies on properties of byproducts (fibre and starch of banana pseudostem) Thorat *et al.* (1997) found that fibre length of 190 cm, diameter 27 μm, firmness 61.20 denier, strength 390 g and elongation 3.25 per cent respectively showed excellent resistance to alkali and many organic solvents.

Srikanth *et al.* (2001) reported that among plant fibres banana fibre possessed large diameter of 80 to 250 μm, cellulose 65 per cent, tenacity 529 to 754 (MN/m^2), elongation 1.0 to 3.5 per cent and pineapple fibre possessed diameter of 20 to 80 mm, cellulose 62 per cent, tenacity 413 (MN/m^2) and elongation 0.8 to 1.0 per cent. Similar studies by Nangia (2001) stated that high cellulose content and low micro fibril angle gave banana fibres better reinforcing efficiency than sisal. Kymalainen *et al.* (2001) reported that abaca fibre from banana plant with density of $1.5 g/cm^3$ and tensile strength $980E^6$ N/m^2 was durable and resistant to seawater.

Mooney (2001) found that lignin rich fibre (jute) showed resistance to weathering since lignin had lower affinity towards moisture and acted as a protective barrier for moisture absorption and delayed retting process compared to cellulose rich fibre (banana).

Bowlin *et al.* (2000) reported that banana fibres contained cellulose 60 to 65 per cent, hemi cellulose 6 to 8 per cent, lignin 5 to 10 per cent and transverse swelling in water 16 to 25 per cent. Similar studies by Becker (2001) in pineapple found that pineapple leaf contained 80 per cent cellulose, 12 per cent lignin and moisture regain at 60 per cent relative humidity.

Chengowen *et al.* (2001) in his study on properties of plant fibres found that banana fibre contained cellulose 50 to 60 per cent, hemicellulose 25 to 30 per cent, pectin 3 to 5 per cent, lignin 12 to 18 per cent, water soluble materials 2 to 3 per cent, fat and wax 3 to 5 per cent and ash 1 to 1.5 per cent. Similarly pineapple fibre contained 56 to 62 per cent cellulose, 16 to 19 per cent hemicellulose, 2 to 2.5 per cent pectin, 9 to 13 per cent lignin, water soluble materials 1 to 1.5 per cent, fat and wax 4 to 7 per cent and ash 2 to 3 per cent.

Kestler *et al.* (2001) in his study on mechanical properties on some natural 1fibres found that banana fibres had a diameter 0.8 to 2.5 mm, density 1350 kg/m^3, young's modulus1.4 Gpa, tensile strength 95 Mpa, elongation break 5.9 per cent and pineapple fibre had a diameter 0.2 to 8.8 mm, young's modulus14.5 Gpa, tensile strength 413 to 1627 Mpa respectively.

2.3 Fibre products

Plant fibres composed of cellulose were short, brittle, slippery and could not be twined woven or spuned but they could be used for manufacture of paper, fibreboard, cellophane and rayon (Canning, 1995). Liu-Zhengchu (1995) studied the physiochemical properties such as thickness, monomer type of sisal fibre and found that sisal fibre was best alternative to glass fibres in dough and bulk moulding components, floor plates, roof tiles and sanitary ware.

Use of banana fibre in natural fibre composites is being attempted now a-days. Composites are materials with lightweight, strength to weight ratio and stiffness, which could replace the conventional materials like metal, wood etc mainly to reduce the cost of raw materials.

Pushkaran (1996) reported that banana fibres could be utilized for making fancy articles like bags of different sorts, table mats, floor mat, belt, pot hangers, card boards, fabrics and tying materials. In combination with other materials, banana fibres could also be used for the manufacture of insulating materials, roofing materials, moisture conservation and carry bags.

Aroracharu (1998) reported that banana leaf fibres dyed and made into yarn were woven into fabrics, which was then used to make various garments. Azer (1999) reported that banana fibre based paper was unique and attractive compared to paper obtained from pulp wood and added that was cheaper to manufacture it free from chemicals and consumed only less energy and water.

Indira (1993) reported that pineapple leaf fibres were used for making products such as paper, reinforced plastics, reinforced roofing and non- woven belt. Hayavadana (1998) found that pineapple leaf fibre blended with polyester staple produced needle bunched non-woven, which had an important position in technical textile.

A systematic study carried out on sisal and jute fibre composites found that plant fibre were light in weight and had excellent bending stiffness besides good thermal and sound insulation with an elastic modulus of 2 Gpa indicating their application in construction sector (Zang-Yuanming, 2000).

Abaca fibre was processed to fibre craft, cordage, fabrics, non-wovens, pulp, different types of papers like currency notes, cigarette papers, stencil papers and other specialty papers requiring high porosity, excellent tear, bursting and tensile strength (Bose, 2000). Jeyachandran *et al.* (2000) found that exceptional strength of abaca fibre and its resistance to the action of salt water. So it was particularly suitable for marine cordage, well drilling cables, hoisting ropes and various other types of ropes. In Japan large quantities of abaca fibre were used for the manufacture of ropes (Lahaussois and Kyrklund, 2001).

Ashby (1998) reported that chemical constituents and ultimate cell dimension of banana fibre compared well with those of jute and mesta and had great potentialities for paper making and textile application.

Srikanth and Datta. (2001) reported that plant fibres were extensively used for cordage, sacks, fishnets, matting, rope and as fillings for mattresses and cushions.

Yu (2001) stated that pineapple fibres had more non-cellulosic materials especially lignin which was used in making ropes, mats and in some other field such as composite materials. Kerski (2002) found that Porolera an ideal pineapple cultivar yielded strong white silky fibre that was used for making fine casting nets and wrapping cigars.

Long fibre technology produced all sorts of fibre of high quality used for paper products (building papers to artistic paper) and in addition had phenomenal strength 3000 times stronger than normal paper (Alexander de blas, 2002)

Revathy (2002) reported that properties like high tear and tensile strength of banana fibre was used to print Japanese yen notes on paper from fibre of banana variety abaca. Similar studies by Suma *et al.* (2002) stated that banana fibres had an excellent strength as high as 44 units of bursting factor and was used in the manufacture of Japanese Yen notes, insulating papers and craft papers. Biswas (2002) reported that banana fibres from a slippery mush was fine thread similar to linen and could be used in textiles in various ways.

Suma *et al.* (2002) opined that banana fibres were used for making yarn, abrasive packing paper, tea bag, handbag, shoes, ribbon, tablemat, toys, flower vases, picture frames, shirts and baskets respectively and also concluded that ropes made from banana fibre was utilized for the manufacture of products similar to coir products like door mats, carpets etc and added that those products had good export market.

Idicula (2003) reported that plant fibres were in general suitable to reinforce plastic due to their relative high specific strength, stiffness and low density and that with the rise of composite materials, there is a renewed interest for natural fibres.

Nair (2004) reported that from 12 to 14 banana pseudostems, one kg of fibre was extracted which was used for making attractive and inexpensive handicraft items that helped women as a source of income in many villages. Similar findings by Martin (2003) stated that banana fibre extraction provided employment to the rural women that can easily develop the skills needed for running a spinning unit.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

The investigation on "Scope of banana and plantain pseudostem sheaths for fibre extraction and its utilization" was carried out in the Department of Processing Technology, College of Horticulture, Kerala Agricultural University, Vellanikkara from February 2003 to August 2004.

A total of three experiments were conducted as detailed below.

3.1 EXPERIMENT I: EVALUATION OF BANANA / PLANTAIN CULTIVARS FOR FIBRE YIELD

The following ten varieties of banana were selected for the study from banana germplasm at Banana Research Station, Kannara under Kerala Agrl University (Plate.1).

Nendran - Musa (AAB)
Palayankodan - Musa (AAB) (Syn: Mysore)
Poovan - Musa (AAB) (Syn: Rasthali)
Monthan - Musa (ABB)
Kanchikela - Musa (ABB)
Karpuravalli - Musa (ABB)
Robusta - Musa (AAA)
Redbanana - Musa (AAA)
Njalipoovan - Musa (AB)
Kunnan - Musa (AB)

3.2 METHODS OF EXTRACTION

3.2.1 Hand extraction

After harvest of the bunch, the pseudostem was carried from field to the extraction centre and leaf sheaths were peeled from the pseudostem, which

Plate 1. Pseudostem of selected banana/plantain varieties

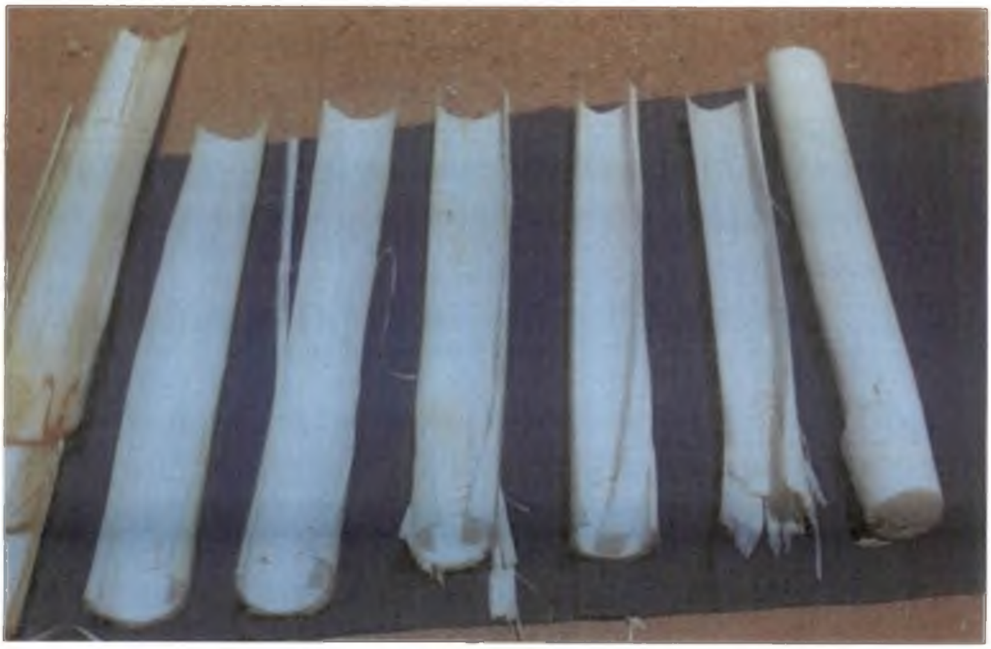


Plate 2. Pseudostem sheaths for fibre extraction

contained about 20 sheaths. These sheaths were grouped into four viz., outer most four, the outer four, middle five and the inner most five. In this outer most two or three sheaths were rejected. As each group of sheath yields different grades of fibre, fibre from different groups were collected separately.

In this method, the sheaths were cut into length of 100cm and spilt into pieces of 6cm to 10cm width (Plate.2). Each piece was placed on a wooden plank, outer side touching the plank. The flesh, juice etc were then scraped by hand with a steel blade (6cm x 5cm) fitted with the wooden handle and by holding the sheath with the other hand. The extractor placed the piece on table and performed a few forward movements of the blade which unveiled the fibre, finally leaving the cleaned fibre in the hands of the extractor (Plate.3).

3.2.2 Machine extraction

In this method the fibre was extracted by Raspador machine. The Raspador machine consists of a drum (33.6 cm in diameter), the carbon steel angle blades (22.8 cm in length) fitted on the periphery of the drum and an adjustable roller with scraping plate in front of the drum.

The shaft carrying the drum was fitted with ball bearings mounted on the framework. The drum rotates (700 to 800 rpm) powered by an electric motor (3 phase, 3 HP) or an oil engine of 5 HP (Plate.4a). The pseudostem sheath was inserted between the adjustable rollers and the rotating drum to the extent of ¾ of the sheath and then drawn back. The other end of the sheath was inserted into the machine by holding the cleaned portion of the sheath. Then the sheath was drawn back slowly and steadily. This process produced clean fibre (Plate.4b and 4c).

The fibre extracted by machine was found to be having remnants of non fibrous material . It was again refined by conventional method of hand extraction.

Plate 3. Extraction of banana fibre by manual method

a. Raspador machine

b. Feeding of sheath

C. Waste material

Plate 4. Extraction of banana fibre by mechanical method

3.2.3 Extraction by retting

In this method sheaths of size 40 cm were taken and treated with the retting agents like sodium chloride, sodium hydroxide, hydrogen peroxide, sodium hypochlorite, *Trichoderma viridae* culture at a concentration of two per cent respectively with water and unretted as control filled in a plastic crate of 25 litre capacity (For *Trichoderma viridae* 40 g of culture was mixed with 20 litres of water). The plastic crates were kept under shade for 10 days and the fibre was extracted by conventional method of hand extraction (Plate.5).

After the extraction of fibres by above methods, the following observations were recorded.

3.2.4 Proximate composition of fibre

Composition of cellulose, lignin content of the fibre was analysed for the representative variety of Nendran (Musa. AAB) from among the ten cultivars selected.

Estimation of holocellulose was carried out as per the procedure. Fibres were cut into small fragments. A known weight of the fibre (5 g) was extracted with ethanol benzene mixture. This was followed by extraction with distilled water. After both these extractions, the material was dried. A buffer solution containing 60 g of glacial acetic acid and 1.3g sodium hydroxide per litre was prepared. 3.3g of the extracted fibre was taken in a three litre round – bottom flask and 42.4 ml of the Buffer solution, 4 ml of distilled water and 4.24 ml of 20 per cent sodium chlorite solution were added to it. The flask was then fitted with an air condenser and placed in a water bath at 75 ^{0} C. Buffer solution (42.4 ml) and 4.24 ml of sodium chlorite were added at intervals of 30, 60, 105 and 150 min from the beginning. During the process, a pH of 3.2 to 3.8 was maintained.

a. Unretted sheath

b. Retted sheath

c. Banana fibre extracted from retted sheaths

Plate 5. Retting of banana pseudostem sheaths

After the termination stage, the product was washed until free from acid. It was finally washed with ethanol, dried and weighed. Knowing the original and final weights, the holocellulose present in the material expressed as the percentage of the total original weight or extracted weight was found out.

Lignin percentage was computec from the difference in weights of the samples obtained prior to and after the ch orination process.

To find the percentage of pure cel ulose, the holocellulose was treated with one per cent sodium hydroxide solution at boil for 30 min. The residue was filtered hot, washed, neutralized with mi d acetic acid, washed further and dried. From the dry weight of pure cellulose so obtained, percentage of cellulose based on extracted dry weight was computed.

Calculations:

Percentage of cellulose based on original dry weight = $(W_4/W_1) \times 100$

Percentage of lignin based on original dry weight = $(W_2-W_3)/W_1 \times 100$

Whereas,

W_1- Original dry weight

W_2- Dry weight after alcohol – benzene and water extraction

W_3- Dry weight after chlorination process, which removes the lignin and leaves the holocellulose intact

W_4- Weight of the dried residue obtained after treatment of holocellulose with one per cent sodium hydroxide.

3.2.5 Anatomy of fibres

It was studied by using the maceration technique. In this technique the macerated material was prepared by Schultz's method (30 per cent nitric acid and a pinch of potassium chlorate). Pieces of banana fibres were taken and then they were boiled in water till they settled at bottom. Then the material was boiled in a mixture of potassium chlorate and 30 per cent nitric acid until the colour changed to blue. The resultant material was thoroughly washed in distilled water till traces of the acid were removed. Finally they were mounted with glycerin jelly on a slide and the observations like fibre diameter, fibre lumen diameter and fibre wall thickness were taken from unbroken fibres.

3.2.6 Length of fibre (cm)

It was measured by using a measuring scale of one-meter length.

3.2.7 Wet fibre yield (g)

Fibres obtained from different sheaths of a pseudostem were pooled and total weight was recorded using an electronic balance (Contech, precision balance).

3.2.8 Dry fibre yield (g)

After extraction the fibres were dried under shade for two to three days and then weighed by using same electronic balance as above.

3.2.9 Percentage recovery of wet fibre yield from sheath

Recovery percentage of fibre was calculated by the following formula

$$\text{Recovery percentage} = \frac{\text{Weight of fibre (g)} \times 100}{\text{Weight of sheath used for extraction (g)}}$$

3.2.10 Visual quality

The visual qualities of different varieties of banana / plantain fibres were assessed by a panel of ten judges. They evaluated the fibres using five point Hedonic scale. The ratings were,

Excellent - 5
Very good - 4
Good - 3
Like - 2
Dislike - 1

3.2.11 Colour

The colour was important for grading of banana / plantain fibres. The colour depends on a number of factors like position of sheath, cleaning efficiency of labour, machine and the material used for extraction.

Due to the above factors colour of the banana / plantain fibre was not judged using sensory techniques, as the results are likely to be erroneous.

3.3 EXPERIMENT II: STANDARDIZATION OF METHODS FOR STORAGE OF BANANA FIBRE.

Banana fibre extracted from selected varieties viz., Robusta, Nendran, Red banana, Monthan and Poovan under Experiment I was subjected to the following treatments

Treatment 1: Open storage in ventilated room (Control).

Treatment 2: Fibres sealed in polythene cover (200gauge)

Treatment 3: Fibres sealed in polythene cover (700gauge)

Treatment 4: As in Treatment 2, but air inside the cover removed with the help of a vaccum pump before sealing.

Treatment 5: As in Treatment 3, but air inside the cover removed with the help of a vaccum pump before sealing.

Treatment 6: Fibre sealed in high density polyethylene (HDPE) covers

Treatment 7: Fibre sealed in loosely woven gunny bag

Treatment 8: Fibres sealed in polythene lined aluminum foil pouch

Treatment 9: As in Treatment 6, air inside the cover are removed with the help of vacuum pump before sealing.

The effect of these treatments on retention of fibre quality was assessed by the following observations at monthly interval for a period of five months.

The physical properties like tensile strength, elongation and density of banana / plantain fibres were carried out by using the Instron Tensile Tester at Central Coir Research Institute (CCRI), Alleppey. A test length of 50 mm was used for selected varieties of banana / plantain fibres. The test speed was adjusted in such a way that all the fibres, irrespective of their extensibility, broke within 20 seconds. The software package suppilied by the Instron Co., was suitably modified. So that test parameters were controlled by the computer and the entire test data was stored in the computer memory. About 50 fibres were tested from each of the thick and thin fibre lots. The average breaking load and breaking elongation values along with CV per cent were directly obtained from the computer data.

3.3.1 Tensile strength (cN/tex)

The resistance offered by the fibre stand against tearing strain or rupture.

3.3.2 Elongation (per cent)

Elongation per cent, which is just the length of fibre sample after it is stretched (*L*), divided by the original length of the sample (L_0), and then multiplied by 100.

$$\text{Elongation (per cent)} = \frac{L \times 100}{L_0}$$

3.3.3 Density (g/cm^3)

Density of the fibre was measured by using the following formulae

$$D = \frac{M}{V}$$

Where,

D – Density of the fibre

M – Mass of the fibre

V – Volume of the fibre

3.4 EXPERIMENT III: ASSESSMENT OF SUITABILITY OF BANANA FIBRE FOR PLAITING AND ROPE MAKING

The banana fibre extracted through the manual method of fibre extraction from different varieties under Experiment I was used for making banana fibre ropes and plaited straps using standard uniform procedures. A qualitative attribute of these ropes and plaited straps was evaluated by the following observations recorded at monthly intervals for a period of three months.

3.4.1 Tensile strength (cN/tex)

The resistance offered by the fibre stand against tearing strain or rupture.

3.4.2 Elongation (per cent)

Elongation per cent, which is just the length of fibre sample after it is stretched (L), divided by the original length of the sample (L_0), and then multiplied by 100.

$$\text{Elongation (per cent)} = \frac{L \times 100}{L_0}$$

3.4.3 Water absorbability (per cent)

The fibre made in the form of plait and rope was soaked in water. The water absorbstion capacity of the fibre was observed periodically at monthly intervals over a period of three months as gain in weight and the gain expressed as percentage.

3.5 STATISTICAL ANALYSIS

Analysis of variance was carried out as per the statistical design of completely randomised design and significance was tested by F- test and the treatments were compared using Duncan's Multiple Range Test (DMRT).

RESULTS

IV. RESULTS

The results of the study conducted in Department of Processing Technology, College of Horticulture, Kerala Agricultural University, Vellanikkara during 2003 – 2004 under the project "Scope of banana and plantain pseudostem sheaths for fibre extraction and its utilization" are presented in this chapter under the following headings.

4.1 METHODS OF EXTRACTION OF FIBRE

4.1.1 Wet fibre yield (g)

4.1.2 Dry fibre yield (g)

4.1.3 Percentage recovery of fibre (per cent)

4.1.4 Length of fibre (cm)

4.1.5 Proximate composition of fibre

4.1.6 Wet fibre yield, dry fibre yield and recovery per cent of Nendran variety under different retting agents

4.1.7 Visual quality of fibre

4.1 METHODS OF EXTRACTION OF FIBRE

4.1.1 Wet fibre yield (g)

The results of wet fibre yield under different methods of extraction are presented in Table 1. Among varieties, maximum fibre yield was obtained for Red Banana (16.5 g), which was on par with Palayankodan (15.8 g). Nendran with wet fibre yield of (13.45 g) was the next best variety. The minimum value (6.11 g) was recorded by Kanchikela under hand extraction. The other varieties like Poovan, Robusta, did not show marked difference for fibre yield.

There was significant difference in the wet fibre yield obtained from the machine extraction using ten varieties. Between varieties, Red Banana recorded the maximum (25.7g), the least yield (1.96g) was recorded by Monthan. Varieties like Robusta and Palayankodan were on par.

On comparison of different methods of extraction on wet fibre yield, machine extraction was significantly superior with the yield of (11.02g) compared to hand extraction (10.53g).

4.1.2 Dry fibre yield (g)

The dry fibre yield from ten varieties, using two methods of extraction ranged from 1.11g to 13.0g and the data are presented in Table 2. With regard to dry fibre production under hand extraction the variety Red Banana was significantly superior with the maximum yield of 6.3 g compared to other varieties. Monthan with the yield of 5.37 g and Nendran 5.62 g were the next best.

On comparison of different varieties subjected to machine extraction, fibre yield from Red Banana recorded the maximum value of 13.0 g and was followed by Nendran with the yield of 6.9 g. The varieties like Njalipoovan, Robusta and Poovan did not show marked difference for dry fibre yield. In this method of extraction, Monthan produced lowest fibre yield of 1.11 g. The other varieties did not show a marked difference for the fibre yield (Plate 6).

Similarly on comparison of different extraction methods, dry fibre yield was maximum (4.69g) under machine extraction compared to hand extraction (4.24g).

Table 1. Comparison of wet fibre yield under different methods of extraction (g)

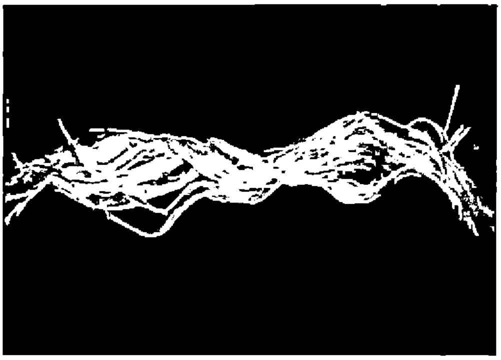
Varieties	Weight of the fibre (g)	
	Hand extraction	Machine extraction
Monthan	7.50^{cd}	6.96^{e}
Red banana	16.50^{a}	25.70^{a}
Njalipoovan	7.90^{cd}	9.50^{cd}
Nendran	13.45^{ab}	10.20^{bc}
Kunnan	8.80^{bcd}	7.20^{d}
Poovan	10.8^{bc}	9.50^{cd}
Robusta	10.11^{bc}	10.00^{bc}
Palayankodan	15.80^{a}	14.50^{b}
Karpooravalli	8.29^{cd}	8.20^{d}
Kanchikela	6.11^{d}	7.40^{d}
Mean	10.53	11.02

In a column, means followed by common letter do not differ significantly at 5 per cent level by DMRT

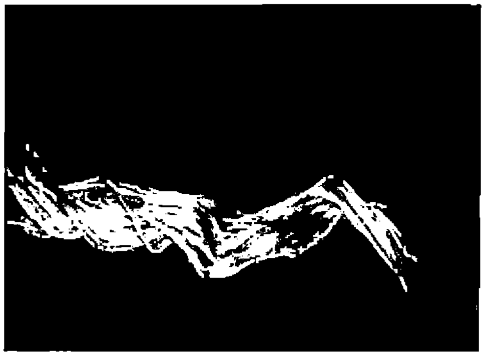
Table 2. Comparison of dry fibre yield under different methods of extraction (g)

Varieties	Weight of the fibre (g)	
	Hand extraction	Machine extraction
Monthan	5.37^{abc}	1.11^{e}
Red Banana	6.3^{bc}	13.00^{a}
Njalipoovan	2.83^{de}	4.2^{bc}
Nendran	5.62^{ab}	6.9^{b}
Kunnan	4.1^{ab}	4.8^{bc}
Poovan	4.4^{bc}	3.5^{bcd}
Robusta	3.7^{bcd}	4.1^{bc}
Palayankodan	1.95^{e}	2.7^{d}
Karpooravalli	4.44^{bcd}	3.4^{cd}
Kanchikela	3.65^{bcd}	3.2^{cd}
Mean	4.24	4.69

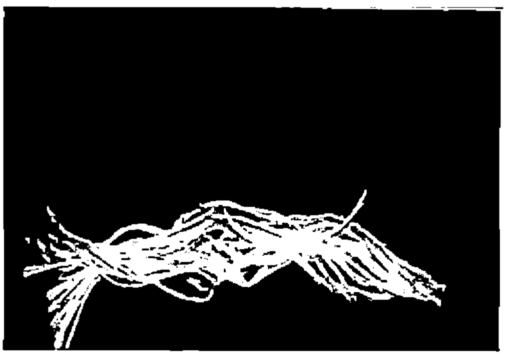
In a column, means followed by common letter do not differ significantly at 5 per cent level by DMRT



a. Red Banana

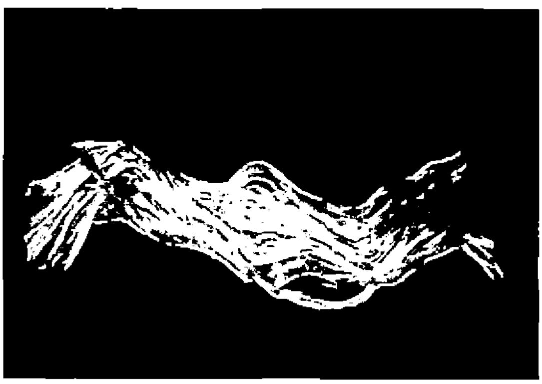


b. Kunnan

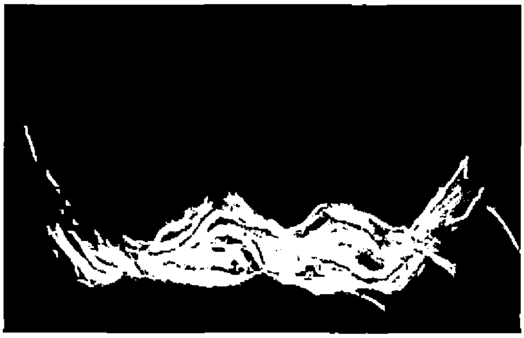


c. Robusta

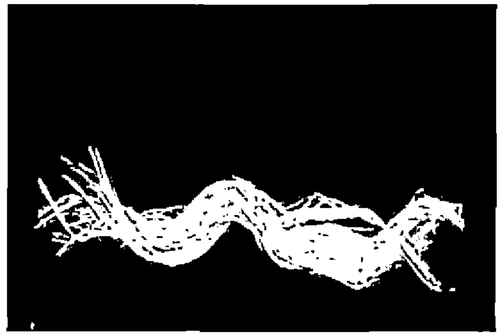
d. Karpooravalli



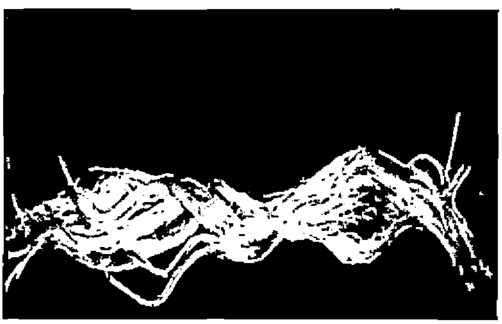
e. Nendran



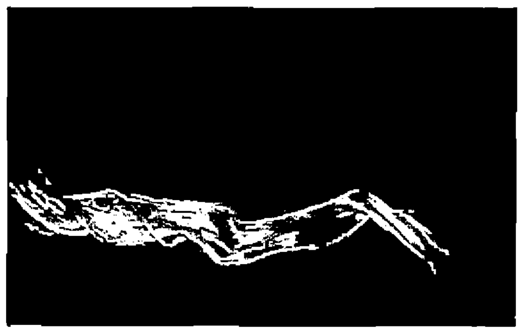
f.Monthan



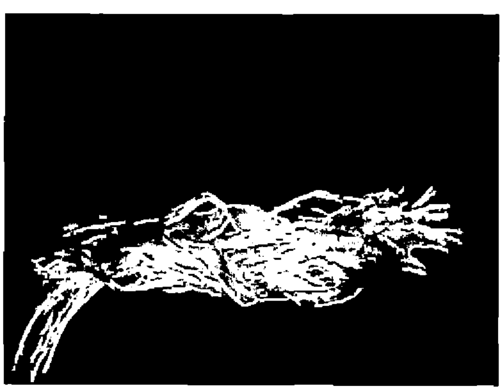
g. Palayagodan



h. Njalipoovan



i. Poovan



j. Kanchikela

Plate 6. Dried banana fibre of selected varieties

4.1.3 Percentage recovery of wet fibre yield from sheath (per cent)

As observed in Table 3, the percentage recovery of banana fibre varied significantly between the varieties as well as between methods of extraction.

Under hand extraction, varieties like Nendran (0.76) and Red Banana (0.62) recorded the maximum recovery percentage. The other varieties like Robusta, Poovan and Njalipoovan recorded the percentage of 0.38, 0.31 and 0.32 respectively. The minimum (0.22) was recorded by Monthan.

On comparison of different varieties under machine extraction, the Nendran variety recorded the maximum (0.71) percentage followed by Poovan (0.66). Minimum (0.27) was recorded by Kanchikela.

4.1.4 Length of fibre (cm)

The results of the length of fibre under two methods of extraction are presented in Table 4. Between varieties, Red Banana significantly recorded the maximum value (94.2 cm), which was on par with Nendran, Karpooravalli and Palayankodan. Minimum value was recorded by Njalipoovan (76.2cm) under hand extraction.

Similarly under machine extraction Red Banana was significantly superior with the maximum length of (95.3 cm) and was on par with Nendran and Poovan (Syn: Rasthali). Karpooravalli recorded the shortest length (72.8 cm), which was on par with Monthan (74.4 cm).

Among methods of extraction on length of fibre, hand extraction rated superior with a length of 85.3cm compared to 79.3cm under length of machine extraction.

Table 3. Comparison of recovery percentage of fibre from total sheath yield under different methods of extraction (g)

Varieties	Recovery percentage (per cent)	
	Hand extraction	Machine extraction
Monthan	0.22[f]	0.29[f]
Red Banana	0.62[b]	0.41[d]
Njalipoovan	0.32[e]	0.64[b]
Nendran	0.76[a]	0.71[a]
Kunnan	0.47[c]	0.57[c]
Poovan	0.31[e]	0.66[b]
Robusta	0.38[d]	0.58[c]
Palayankodan	0.48[c]	0.54[c]
Karpooravalli	0.39[d]	0.37[e]
Kanchikela	0.31[e]	0.35[e]
Mean	0.43	0.51

In a column, means followed by common letter do not differ significantly at 5 per cent level by DMRT

Table 4. Comparison of length of fibre under different methods of extraction (cm)

Varieties	Length of fibre (cm)	
	Hand extraction	Machine extraction
Monthan	74.5[c]	74.4[c]
Red Banana	92.7[a]	95.2[a]
Njalipoovan	76.2[c]	74.9[c]
Nendran	90.7[a]	93.9[a]
Kunnan	92.3[a]	93.1[a]
Poovan	83.2[b]	85.6[b]
Robusta	73.6[c]	66.1[d]
Palayankodan	92.9[a]	63.9[d]
Karpooravalli	94.2[a]	72.8[c]
Kanchikela	82.3[b]	74.6[c]
Mean	85.3	79.3

In a column, means followed by common letter do not differ significantly at 5 per cent level by DMRT

4.1.5 Proximate composition of fibre

The results of the cellulose and lignin content under hand extraction of Nendran variety was 62.0 per cent and 11.0 per cent respectively. Under machine extraction the cellulose and lignin content were 60.25 per cent and 10.19 per cent respectively (Table 5).

4.1.6 Effect of different retting agents on wet fibre yield, dry fibre yield and recovery per cent in Nendran variety

Under different retting agents, the wet fibre yield, dry fibre yield and recovery percentage of Nendran variety differed significantly and the relevant data are presented in Table 6.

Among various retting agents sodium hydroxide (two per cent) recorded the maximum (12.2g) wet fibre yield, which was on par with hydrogen peroxide. The minimum (3.98g) yield was recorded in sodium hypo chlorite.

With regard to dry fibre yield, hydrogen peroxide was significantly superior to other retting agents with the maximum (6.54g) yield which was on par with sodium hydroxide (6.31g). Minimum yield (2.41g) recorded by sodium hypochlorite.

On comparison with recovery percentage, sodium hydroxide recorded the maximum (81.20 per cent), which was on par with hydrogen peroxide (77.60 per cent). The minimum (52.00 per cent) recovery percentage was recorded by *Trichoderma viridi*. These results are presented in Table 6.

4.1.7 Visual quality

The visual quality of different varieties of banana / plantain fibres showed variation (Table 7). Under machine extraction, varieties like Poovan and

Table 5. Chemical composition of banana fibre variety Nendran

Sl.No	Method of extraction	Chemical composition (per cent)	
		Cellulose	Lignin
1.	Hand extraction	62.00	11.00
2.	Machine extraction	60.25	10.19

Not analysed statistically

Table 6. Wet fibre yield, dry fibre yield and recovery per cent of Nendran variety under different retting agents

Retting agents	Wet yield (g)	Dry yield (g)	Recovery percentage (per cent)
Sodium hypo chlorite	3.98[d]	2.41[c]	0.20[c]
Hydrogen peroxide	12.1[a]	6.54[a]	0.54[a]
Sodium chloride	7.21[b]	3.81[b]	0.32[b]
Sodium hydroxide	12.2[a]	6.31[a]	0.53[a]
Trichodermma viride	5.81[c]	3.78[b]	0.32[b]
Water	5.01[c]	2.81[c]	0.23[c]

In a column, means followed by common letter do not differ significantly at 5 per cent level by DMRT

Palayankodan recorded maximum (38.0) value, which was followed by Njalipoovan, Karpooravalli and Robusta. Varieties like Red Banana and Kanchikela recorded minimum (12.0) values. Under hand extraction, varieties like Palalyankodan and Poovan produced high quality (41 and 40 respectively) fibre, while low quality was produced by Red Banana and Kanchikela.

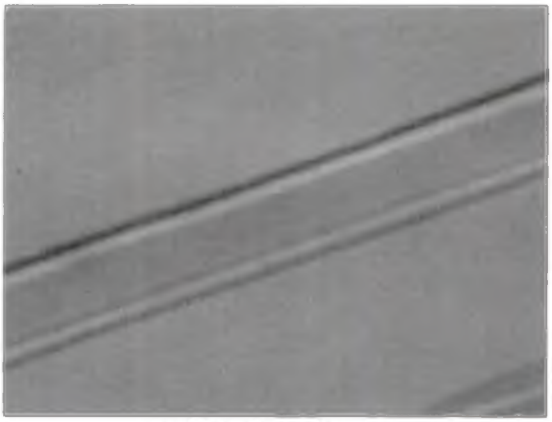
Among the methods of extraction, fibre obtained under hand extraction was rated as best (27.2).

4.1.8 Anatomy of fibres of different banana / plantain varieties

Study of the anatomy of banana / plantain fibres with respect to fibre thickness, lumen width and fibre wall thickness did not show any significant difference between the varieties (Plate 7). However, maximum fibre thickness (47.7μm) and lumen width (38.0μm) was recorded by Palayankodan and maximum (5.4μm) fibre wall thickness was recorded by Njalipoovan, which was followed by Robusta as observed in Table 8.

4.2 STANDARDIZATION OF METHODS FOR STORAGE OF BANANA FIBRE

The following physical parameters were analysed under different storage methods over a period of five months for selected banana varieties like Robusta, Red Banana, Poovan (Rasthali), Nendran and Palalyankodan (Plate 8 and 9).


a. Kanchekela

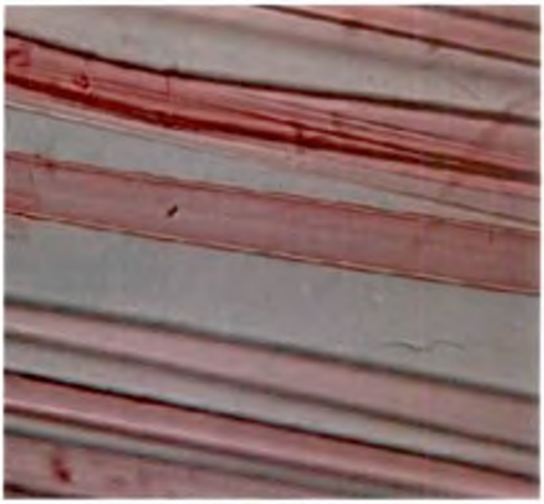

b. Karpooravalli


c. Kunnan

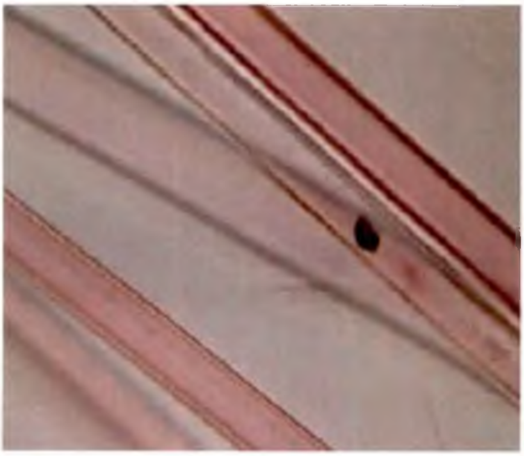

d. Monthan


e. Nendran

f. Njalipoovan



g. Palayankodan



h. Poovan

i. Red Banana

j. Robusta

Plate 7. Anatomy of banana fibre of selected varieties

Table 7. Visual quality of different varieties of banana / plantain fibres

Varieties	Total score	
	Machine extracrion	Hand extraction
Monthan	18	21
Red banana	12	14
Njalipoovan	32	32
Nendran	28	28
Kunnan	18	20
Poovan	38	40
Robusta	32	34
Palayankodan	38	41
Karpooravalli	28	28
Kanchikela	12	14
Mean	20.0	27.2

Not analysed statistically

Table 8. Anatomy of banana fibres of different varieties

Varieties	Cell thickness (μ)	Lumen width (μ)	Cell wall thickness (μ)
Monthan	46.78[a]	36.44[a]	5.16[a]
Red Banana	42.75[a]	32.46[a]	5.14[a]
Njalipoovan	33.69[a]	22.76[a]	5.46[a]
Nendran	45.95[a]	36.32[a]	4.81[a]
Kunnan	35.38[a]	24.94[a]	5.21[a]
Poovan	42.80[a]	33.14[a]	4.82[a]
Robusta	38.50[a]	27.88[a]	5.30[a]
Palayankodan	47.71[a]	38.09[a]	4.81[a]
Karpooravalli	36.25[a]	27.36[a]	4.44[a]
Kanchikela	32.42[a]	23.96[a]	4.22[a]

In a column, means followed by common letter do not differ significantly at 5 per cent level by DMRT

4.2.1 Effect of storage methods and its influence on tensile strength of banana fibre of different varieties

4.2.1.1 Robusta

Methods and duration of storage for banana fibre variety Robusta differed significantly in tensile strength between treatments and within treatments as indicated in Table 9. However, the interaction effect was not significant.

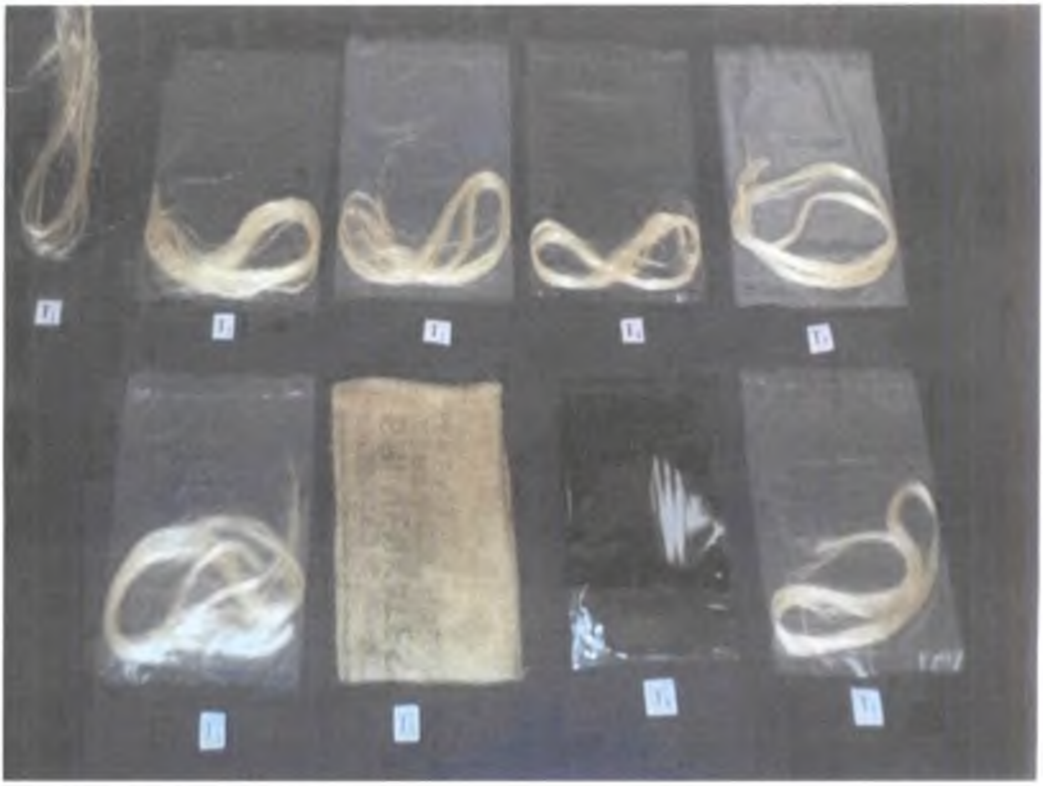
Among different methods of storage T_9 (HDPE cover without vaccum) recorded the maximum (76.81 cN/tex) tensile strength followed by T_5 (700 gauge polythene cover with out vaccum). The minimum tensile strength was recorded by T_1 (open storage condition). The other treatments did not show a marked difference for tensile strength.

Mean tensile strength was maximum (67.93 cN/tex) in first month after storage (M_1), which was on par with second month storage (M_2). M_3, M_4 and M_5 showed a stable tensile strength of 66.63 cN/tex, 66.18 cN/tex and 66.13 cN/tex respectively without much difference between them.

4.2.1.2 Nendran

As observed in Table 10, the tensile strength of banana fibre variety Nendran differed significantly between treatments and within treatments. However, no significant interaction was observed.

On comparison of different storage methods, fibre stored under T_9 (HDPE cover without vaccum) recorded the maximum (56.54 cN/tex) tensile strength followed by T_5 (700 gauge polythene cover with out vaccum) (55.03 cN/tex). In this treatment, T_1 (open storage condition) recorded the minimum (38.04 cN/tex) tensile strength.



Treatment 1: Open storage in ventilated room.

Treatment 2: Fibres sealed in polythene bag (200guage)

Treatment 3: Fibres sealed in polythene bag (700guage)

Treatment 4: As in treatment 2, but air inside the bag removed with the help of a vaccum pump before sealing.

Treatment 5: As in treatment 3, but air inside the bag removed with the help of a vaccum pump before sealing.

Treatment 6: Fibre sealed in plastic sacks

Treatment 7: Fibre sealed in loosely woven gunny bag

Treatment 8: Fibres sealed in polythene lined foil pouch

Treatment 9: As in treatment 6, air inside the bag was removed with the help of vacuum pump before sealing.

Plate 8. Different storage treatments of banana fibre

a. Instron Tensile Tester

b. Banana fibre placed for testing

Plate 9. Equipment used for testing physical properties of banana / plantain fibres

Table 9. Methods of storage and its influence on tensile strength (cN/tex) of banana fibre of Robusta

Months after storage	Storage treatments									Tensile strength (cN/tex)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	59.21	63.20	65.14	71.77	73.25	68.16	62.28	70.10	78.26	67.93
M_2	59.18	63.16	65.00	71.30	73.15	67.90	61.87	70.01	78.06	67.62
M_3	56.10	61.86	63.73	71.28	72.07	67.70	60.83	69.88	76.13	66.63
M_4	55.14	61.76	62.11	70.84	72.02	67.70	60.79	69.44	75.80	66.18
M_5	55.13	61.80	62.06	70.79	72.00	67.39	60.78	69.36	75.81	66.13
Mean	56.95	62.16	63.61	71.19	72.50	67.80	61.31	69.76	76.81	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

Table 10. Methods of storage and its influence on tensile strength (cN/tex) of banana fibre of Nendran

Months after storage	Storage treatments									Tensile strength (cN/tex)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	39.21	50.13	51.26	55.07	56.18	51.03	43.22	54.21	57.30	50.88
M_2	38.12	50.03	50.41	54.10	55.90	50.21	43.07	54.12	57.10	50.56
M_3	37.90	49.53	50.00	53.93	54.51	49.98	42.52	53.06	57.01	49.83
M_4	37.50	49.50	49.07	53.50	54.30	49.13	42.43	53.01	57.01	49.44
M_5	37.50	49.50	49.07	53.00	54.28	49.10	41.03	53.00	56.40	49.22
Mean	38.04	49.57	49.96	53.95	55.03	49.90	42.45	53.51	56.84	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

With respect of storage months M_1 (first month) and M_2 (second month) were on par and recorded maximum tensile strength of 50.88 cN/tex and 50.56 cN/tex respectively. The months M_3, M_4 and M_5 were on par.

4.2.1.3 Palayankodan (Syn: Mysore)

The data collected from storage of banana fibre of variety Palayankodan under nine treatments over a period of five months are presented in Table 11.

The methods of storage and months after storage had significant influence on the tensile strength of banana fibre in the variety Palayankodan. However, the interaction between methods of storage and months after storage did not produced any significant effect. Banana fibre stored under T_9 (HDPE cover without vaccum) recorded the maximum tensile strength (51.82 cN/tex), which was on par with T_5 (700 gauge polythene cover without vaccum). T_1 (open storage condition) recorded the minimum (42.48 cN/tex) tensile strength.

With regard to months after storage, first month and second month after storage recorded the maximum tensile strength (48.40 cN/tex and 48.18 cN/tex respectively).

4.2.1.4 Poovan (Rasthali)

A significant difference in tensile strength was recorded over a period of five months of storage time under different storage methods of banana fibre in variety Poovan. The data are presented in Table 12.

The treatment T_9 (HDPE cover without vaccum) recorded the highest tensile strength (67.78 cN/tex) and was superior to other storage methods in this regard. This character in the case of T_5 (700 gauge polythene cover without vaccum) and T_8 were

Table 11. Methods of storage and its influence on tensile strength (cN/tex) of banana fibre of Palayankodan

Months after storage	Storage treatments									Tensile strength (cN/tex)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	44.01	45.17	47.23	50.20	51.76	49.07	45.30	49.50	53.41	48.40
M_2	43.28	44.90	47.11	50.09	51.60	48.81	45.11	49.10	53.30	48.18
M_3	43.01	44.16	46.24	49.21	51.00	48.53	43.10	48.30	52.08	47.29
M_4	41.07	43.04	46.13	49.20	51.00	46.13	43.04	48.30	50.22	46.48
M_5	41.04	42.99	46.09	49.17	50.89	46.09	42.96	48.06	50.08	46.40
Mean	42.48	44.06	46.56	49.57	51.23	47.81	43.91	48.65	51.82	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

Table 12. Methods of storage and its influence on tensile strength (cN/tex) of banana fibre of Poovan

Months after storage	Storage treatments									Tensile strength (cN/tex)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	53.07	59.81	57.21	65.06	67.22	62.81	58.21	63.23	68.20	61.65
M_2	53.06	59.01	56.91	65.00	67.01	62.73	58.06	63.01	68.02	61.42
M_3	51.30	57.31	56.82	63.13	66.80	61.84	56.21	61.91	68.00	60.37
M_4	51.11	57.29	53.20	61.01	66.70	61.55	55.07	61.88	67.31	59.46
M_5	50.09	57.03	53.20	61.00	66.39	61.52	55.04	61.85	67.28	59.36
Mean	51.89	58.10	55.47	63.04	66.83	62.11	56.22	62.38	67.78	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

the next best ranging from 66.83 cN/tex to 62.38 cN/tex. The fibre stored under T_1 (open storage condition), however, had a lowest value of 51.89 cN/tex.

On comparison of months after storage, M_1 and M_2 were on par with each other with the values of 61.65 cN/tex and 61.42 cN/tex respectively and other values over a period of time did not mark significant difference for tensile strength.

4.2.1.5 Red Banana

The results of tensile strength obtained under different storages over a period of five months are presented in Table 13.

Among storage methods, T_9 (HDPE cover without vaccum) was significantly superior with the maximum tensile strength of 47.62 cN/tex, which was followed by T_5 (700 gauge polythene cover without vaccum) (45.59 cN/tex). The minimum tensile strength was recorded in T_1 (open storage condition) (33.79 cN/tex).

As can be observed in Table 13, the tensile strength of banana variety Red Banana recorded the highest (43.27 cN/tex) during first month (M_1) of storage that was closely followed by M_2 with a value of 42.64 cN/tex.

4.2.2 Effect of storage methods and its influence on elongation of banana fibre of different varieties

4.2.2.1 Robusta

The influence of storage methods on elongation of fibre over a period of time is presented in Table 14.

Among different storage methods, T_9 (HDPE cover without vaccum) significantly recorded the maximum (1.56 per cent) elongation and was on par with

Table 13. Methods of storage and its influence on tensile strength (cN/tex) of banana fibre of Red Banana

Months after storage	Storage treatments									Tensile strength (cN/tex)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	38.13	41.03	39.10	46.07	48.07	43.20	38.33	47.20	48.52	43.27
M_2	36.51	40.31	38.41	45.81	47.57	42.51	37.90	46.51	48.50	42.64
M_3	35.07	39.83	37.14	45.13	46.42	41.83	37.08	46.21	47.21	41.72
M_4	34.61	38.17	37.10	44.82	43.04	41.66	37.00	42.08	47.20	40.56
M_5	34.60	38.06	37.09	44.11	42.92	41.17	36.10	41.99	47.10	39.26
Mean	33.79	39.48	37.79	45.19	45.59	41.94	37.32	44.76	47.62	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

Table 14. Methods of storage and its influence on elongation (per cent) of banana fibre of Robusta

Months after storage	Storage treatments									Elongation (per cent)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	1.24	1.36	1.29	1.24	1.63	1.35	1.19	1.42	1.65	1.38[a]
M_2	1.20	1.32	1.28	1.22	1.61	1.32	1.19	1.42	1.58	1.35[b]
M_3	1.18	1.32	1.28	1.22	1.56	1.31	1.18	1.38	1.55	1.33[c]
M_4	1.03	1.28	1.26	1.09	1.41	1.31	1.15	1.35	1.51	1.27[d]
M_5	1.01	1.28	1.25	1.01	1.40	1.31	1.15	1.35	1.50	1.25[e]
Mean	1.13[h]	1.31[d]	1.28[d]	1.14[g]	1.53[a]	1.32[d]	1.17[f]	1.39[c]	1.56[a]	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

T_5 (700 gauge polythene cover without vaccum). The minimum (1.13 per cent) was in case of control T_1.

Similarly among months after storage M_1 significantly recorded maximum (1.38 per cent) elongation and was followed by M_2 (1.35 per cent). The treatments M_3, M_4 and M_5-recorded a comparatively stable value.

Treatment and storage method interaction over a period of time on elongation of fibre was found to be significant. The treatment T_9 (HDPE cover without vaccum) over a period of one month after storage recorded the maximum (1.56 per cent) elongation and was on par with T_5 (700 gauge polythene cover without vaccum). Minimum was recorded in control over a period of one month storage.

4.2.2.2 Nendran

The elongation value of fibre of plantain cultivar Nendran varied significantly between different storage methods (Table. 15).

On comparison of treatments fibres, it was observed that stored under T_9 (HDPE cover without vaccum) recorded highest (4.79 per cent). In this treatment the least value (2.99 per cent) was recorded in T_1 (open storage condition). Similarly in storage methods over a period of time M_1 recorded the maximum (4.29 per cent) elongation and other treatments M_2, M_3, M_4 and M_5 did not show marked difference for elongation of fibre.

The interaction of storage methods and duration of storage produced significant influence on elongation of fibre (Table. 15). Maximum value was recorded in T_9 (HDPE cover without vaccum) over a period of one month and minimum (2.93 per cent) was recorded by control (T_1) over a period of five months.

Table 15. Methods of storage and its influence on elongation (per cent) of banana fibre of Nendran

Months after storage	Storage treatments									Elongation (per cent)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	3.88	4.22	4.14	4.90	5.08	4.36	4.03	4.79	5.29	4.53
M_2	3.77	4.19	4.09	4.88	5.08	4.25	3.97	4.77	5.28	4.48
M_3	3.74	4.18	4.08	4.81	5.00	4.17	3.82	4.70	5.24	4.43
M_4	3.61	4.10	3.97	4.70	4.91	4.15	3.82	4.60	5.12	4.33
M_5	3.57	4.10	3.96	4.70	4.85	4.14	3.76	4.60	5.11	4.31
Mean	3.72	4.16	4.05	4.81	4.99	4.22	3.88	4.71	5.21	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

Table 16. Methods of storage and its influence on elongation (per cent) of banana fibre of Palayankodan

Months after storage	Storage treatments									Elongation (per cent)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	1.90	2.15	2.01	3.20	3.53	2.75	1.85	3.01	3.83	2.69^{a}
M_2	1.83	2.08	1.94	3.18	3.48	2.69	1.79	2.97	3.72	2.63^{b}
M_3	1.72	2.01	1.81	3.01	3.41	2.67	1.68	2.95	3.68	2.55^{c}
M_4	1.60	2.01	1.75	2.92	3.21	2.42	1.68	2.69	3.68	2.45^{d}
M_5	1.61	1.93	1.74	2.91	3.20	2.41	1.68	2.60	3.68	2.43^{d}
Mean	1.73^{i}	2.04^{f}	1.86^{g}	3.04^{c}	3.37^{b}	2.59^{e}	1.74^{h}	2.89^{d}	3.72^{a}	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

4.2.2.3 Palayankodan

As can be observed from Table 16, elongation of fibre differed significantly between methods as well as any duration of storage. The interaction storage methods and duration of storage was also significant.

Banana fibre stored under T_9 (HDPE cover without vaccum) produced maximum (3.72 per cent) elongation, which was followed by the next best T_5 (700 gauge polyethylene cover without vaccum) with the elongation of 3.37 per cent. Fibres stored under control produced minimum of 1.76 per cent elongation.

4.2.2.4 Poovan (Rasthali)

The results of elongation of banana fibre variety Poovan (Rasthali) obtained under different storage treatments over a per od of time are presented in Table 17.

As can be observed from Table 17, the elongation of banana fibre in variety Poovan recorded the highest (5.21 per cent) value under T_9 (HDPE cover without vaccum), which was on par with T_5 (4.9° per cent) (700 gauge polythene cover without vaccum). The least value (3.72 per cent) was recorded by control T_1 (open storage condition).

With regard to effect of month after storage, first and second months recorded maximum elongation of 4.53 per cent and 4 48 per cent respectively.

The interaction of storage methods and time period produced significant influence on elongation of fibre (Table 17). The combination T_9M_1 produced maximum (5.29 per cent) elongation and $_1M_1$ produced minimum (3.80 per cent) elongation.

4.2.2.5 Red Banana

The data on elongation value of Red Banana fibre varied significantly between storage methods and months after storage and the same is presented in Table 18.

Banana fibre stored under T_0 (HDPE cover without vaccum) recorded the maximum (6.38 per cent) elongation. The fibre stored under T_1 (open storage condition) recorded the minimum (4.28 per cent) elongation.

On comparison of the different storage treatments over a period of time, the fibre stored under M_1 significantly recorded the maximum (5.82 per cent) elongation. The other treatments M_2, M_3 were the next best with the value of 5.72 per cent and 5.60 per cent respectively.

4.2.3 Effect of storage methods on density of banana fibre of different varieties

The physical parameter density did not show any significant variation between the methods of storage and during time period. However the varieties showed significant difference for the same (Table 19a, b, c, d and e).

Among varieties, maximum fibre density was recorded by Nendran ranging from 2.24 g/cm^3 to 1.61 g/cm^3 over a period of five months storage. This was closely followed by Red Banana 2.2 g/cm^3 to 1.25g/cm^3. Robusta and Poovan (Rasthali) did not show any marked difference between them. Minimum density ranging from 2.08 g/cm^3 to 1.38 g/cm^3 was recorded in Palayankodan (Mysore).

Table 17. Methods of storage and its influence on elongation (per cent) of banana fibre of Poovan

Months after storage	Storage treatments									Elongation (per cent)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	3.88	4.22	4.14	4.90	5.08	4.36	4.03	4.79	5.29	4.53^{a}
M_2	3.77	4.19	4.09	4.88	5.08	4.25	3.97	4.77	5.28	4.48^{b}
M_3	3.74	4.18	4.08	4.81	5.00	4.17	3.82	4.70	5.24	4.43^{c}
M_4	3.61	4.10	3.97	4.70	4.91	4.15	3.82	4.60	5.12	4.33^{d}
M_5	3.57	4.10	3.96	4.70	4.85	4.14	3.76	4.60	5.11	4.31^{d}
Mean	3.72^{g}	4.16^{d}	4.05^{e}	4.81[illegible]	4.99^{b}	4.22^{d}	3.88^{f}	4.71^{c}	5.21^{a}	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

Table 18. Methods of storage and its influence on elongation (per cent) of banana fibre of Red Banana

Months after storage	Storage treatments									Elongation (per cent)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
M_1	4.49	5.74	5.60	6.20	6.40	5.89	5.53	6.07	6.51	5.82^{a}
M_2	4.38	5.74	5.51	6.03	6.38	5.76	5.31	5.96	6.42	5.72^{b}
M_3	4.19	5.55	5.41	5.90	6.21	5.74	5.30	5.70	6.38	5.60^{c}
M_4	4.18	5.33	5.11	5.90	6.18	5.62	5.26	5.70	6.30	5.51^{d}
M_5	4.15	5.30	5.10	5.80	6.18	5.10	5.26	5.68	6.27	5.44^{d}
Mean	4.28^{g}	5.55^{c}	5.33[illegible]	5.98^{c}	6.27^{b}	5.62^{c}	5.34^{f}	5.83^{d}	6.38^{a}	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

Table 19 a. Methods of storage and its influence on density (g/cm^3) of banana fibre of Robusta

Months after storage	Storage treatments									Density (g/cm^3)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean*
M_1	1.98	1.97	1.97	1.88	2.09	1.87	1.86	1.88	1.86	1.92^{a}
M_2	1.91	1.92	1.94	1.86	1.87	1.85	1.81	1.84	1.82	1.87^{a}
M_3	1.81	1.81	1.79	1.81	1.79	1.80	1.77	1.79	1.75	1.81^{a}
M_4	1.75	1.74	1.74	1.54	1.55	1.51	1.76	1.76	1.72	1.67^{a}
M_5	1.48	1.48	1.54	1.52	1.45	1.48	1.63	1.64	1.58	1.53^{a}
Mean*	1.78^{a}	1.79^{a}	1.80^{a}	1.72^{a}	1.75^{a}	1.70^{a}	1.76^{a}	1.78^{a}	1.74^{a}	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT
*Main effect NS

Table 19 b. Methods of storage and its influence on density (g/cm^3) of banana fibre of Nendran

Months after storage	Storage treatments									Density (g/cm^3)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean*
M_1	2.32	2.31	2.30	2.26	2.27	2.28	2.16	2.16	2.17	2.24^{a}
M_2	2.05	2.09	2.09	2.04	2.04	2.03	2.06	2.07	2.06	2.05^{a}
M_3	2.04	2.05	2.08	1.99	1.99	1.99	1.96	1.95	1.94	1.99^{a}
M_4	1.95	1.90	1.91	1.95	1.98	1.99	1.95	1.94	1.94	1.94^{a}
M_5	1.88	1.87	1.87	1.88	1.88	1.83	1.66	1.66	1.65	1.61^{a}
Mean*	2.04^{a}	2.04^{a}	2.05^{a}	2.02^{a}	2.01^{a}	2.02^{a}	1.95^{a}	1.94^{a}	1.95^{a}	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT
*Main effect NS

Table 19 c. Methods of storage and its influence on density (g/cm^3) of banana fibre of Palayankodan

Months after storage	Storage treatments									Density (g/cm^3)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean*
M_1	2.16	2.17	2.13	2.08	2.08	2.10	2.02	2.01	1.99	2.08^a
M_2	1.80	1.79	1.78	2.03	2.05	2.04	1.99	1.99	1.98	1.93^a
M_3	1.68	1.68	1.63	1.80	1.80	1.80	1.87	1.85	1.84	1.77^a
M_4	1.62	1.61	1.61	1.55	1.55	1.60	1.81	1.80	1.83	1.67^a
M_5	1.45	1.45	1.46	1.37	1.40	1.40	1.31	1.30	1.32	1.38^a
Mean*	1.74^a	1.74^a	1.72^a	1.76^a	1.78^a	1.79^a	1.80^a	1.79^a	1.79^a	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT
*Main effect NS

Table 19 d. Methods of storage and its influence on density (g/cm^3) of banana fibre of Poovan

Months after storage	Storage treatments									Density (g/cm^3)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean*
M_1	2.10	2.08	2.07	2.03	2.05	2.03	2.11	2.09	2.10	2.07^a
M_2	2.05	2.07	2.06	1.96	1.97	1.97	2.08	1.97	1.98	2.01^a
M_3	2.02	2.02	2.04	1.96	1.96	1.95	2.06	1.97	1.97	1.99^a
M_4	1.90	1.99	1.92	1.93	1.92	1.92	2.02	1.92	1.96	1.93^a
M_5	1.41	1.42	1.43	1.70	1.70	1.70	2.00	1.80	1.84	1.70^a
Mean*	1.90^a	1.89^a	1.90^a	1.91^a	1.92^a	1.91^a	2.05^a	1.95^a	1.97^a	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT
*Main effect NS

Table 19 e. Methods of storage and its influence on density (g/cm^3) of banana fibre of Red Banana

Months after storage	Storage treatments									Density (g/cm^3)
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean*
M_1	1.96	1.97	1.95	2.10	2.10	2.20	2.10	2.16	2.20	2.08^{a}
M_2	1.95	1.94	1.92	2.00	1.98	2.10	1.90	2.00	2.10	1.98^{a}
M_3	1.94	1.94	1.90	1.89	1.97	2.00	1.96	1.94	1.98	1.94^{a}
M_4	1.94	1.90	1.89	1.74	1.84	1.89	1.89	1.83	1.84	1.86^{a}
M_5	1.89	1.81	1.87	1.68	1.67	1.70	1.70	1.60	1.25	1.86^{a}
Mean*	1.93^{a}	1.91^{a}	1.90^{a}	1.88^{a}	1.91^{a}	1.97^{a}	1.91^{a}	1.90^{a}	1.87^{a}	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT
*Main effect NS

4.3 ASSESSMENT OF SUITABILITY OF BANANA FIBRE FOR PLAITING AND ROPE MAKING

4.3.1 Water absorbability of plait (per cent)

The water absorbability character of the plait made by the extracted fibre varied significantly between varieties and also during soaking time of three months storage (Table 20).

Among the varieties, the water absorbability character was maximum (241.48 per cent) for Palayankodan, which was followed by Poovan (200.00 per cent), Nendran (178.40 per cent) and Monthan (174.60 per cent). Minimum (139.13 per cent) water absorbability was recorded by Kunnan. The other varieties Red Banana (144.61per cent), Robuta (146.80 per cent) and Kanchikela (145.20 per cent) did not show any marked difference for water absorbability.

On comparison of period of storage, water absorbability was maximum (169.62 per cent) during first month. Second month and third month of storage did not show any marked difference for water absorbability.

4.3.2 Water absorbability of rope (per cent)

Rope made of the extracted fibre under Experiment I vary and subjected to water absorbability potential was found to be significant. However, the period of storage did not show any marked difference for water absorbability pattern.

Between varieties, Palayankodan was significantly superior with the maximum (204.13 per cent) water absorbability followed by Poovan (169.20 per cent). The other varieties like Robusta and Nendran did not show any marked

Table 20. Methods of storage and its influence on water absorbability (per cent) of plaits and ropes different banana and plantain varieties

Varieties	Water absorbability (per cent)							
	Plaits				Ropes			
	M_1	M_2	M_3	Mean*	M_1	M_2	M_3	Mean*
Robusta	147.60	146.60	146.30	146.88^g	139.93	138.28	138.12	138.78^c
Nendran	178.80	178.40	178.00	178.40^c	118.85	118.67	118:02	118.50^f
Monthan	177.10	177.00	169.80	174.68^c	120.94	120.32	120.01	120.42^e
Palayankodan	242.80	242.10	240.00	241.48	204.25	204.12	204.01	204.13^a
Red Banana	144.78	144.70	144.29	144.61^h	114.83	114.67	114.08	114.53^h
Njalipoovan	162.24	162.12	162.02	162.13^e	117.81	117.44	117.13	117.46^g
Karpooravalli	158.30	158.21	158.02	158.19^f	124.81	124.65	123.44	124.30^d
Kunnan	139.20	139.10	139.02	139.13^j	107.64	107.33	107.17	107.13^i
Kanchikela	145.20	145.12	145.02	145.13^i	121.25	120.56	120.12	120.64^e
Poovan	200.65	200.03	199.67	200.18^b	169.37	169.23	169.02	169.20^b
Mean*	169.62^a	169.36^b	168.25^c		133.97^a	133.52^b	133.10^c	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

*Main effect- Significant

Interaction effect Significant M_1 – First motnh M_2- Second month M_3 – Third month

difference among them for water absorbability. The minimum value (114.53 per cent) was recorded by Kunnan.

The water absorbability character of rope over a period of three months storage did not show any significant variation. They all showed the stable value ranging from 133.97 per cent to 133.10 per cent (Table 20).

4.3.3 Tensile strength of plait (cN/tex)

Tensile strength of plait varied significantly between varieties and between periods of storage.

Among varieties, tensile strength was significantly high in Robusta (675.77cN/tex), which was on par with Nendran (672.40 cN/tex). It was closely followed by the next best variety Poovan (611.11 cN/tex). Minimum (381.88 cN/tex) was recorded by Kanchikela (Table 21).

On comparison of period of storage, the maximum (572.46 cN/tex) tensile strength was noted during first month of storage and next two months showed a stable value of 558.90 cN/tex and 553.23 cN/tex respectively without significant variation.

4.3.4 **Tensile strength of rope (cN/tex)**

As can be observed from Table 21, the varieties and period varied significantly for tensile strength of rope, made of extracted fibre.

Between varieties, tensile strength was significantly high in Robusta (468.60 cN/tex), which was on par with Nendran (466.40 cN/tex). Poovan with the tensile strength of 426.40 cN/tex was the next best. The other varieties Monthan, Palayankodan and Red Banana did not show any marked difference between them. Kanchikela recorded the least (234.30 cN/tex) tensile strength.

Table 21. Methods of storage and its influence on tensile strength (cN/tex) of plaits and ropes different banana and plantain varieties

Varieties	Tensile strength (cN/tex)							
	Plaits				Ropes			
	M_1	M_2	M_3	Mean*	M_1	M_2	M_3	Mean*
Robusta	691.30	673.00	663.00	675.77[a]	482.46	466.00	458.00	468.70[b]
Nendran	680.00	670.00	666.66	672.40[a]	473.33	468.00	458.00	466.40[c]
Monthan	588.30	568.00	563.00	573.22[c]	377.83	353.60	348.00	359.60[f]
Palayankodan	492.00	482.00	476.60	483.55[e]	381.00	368.00	361.30	370.10[e]
Red Banana	511.66	502.60	496.60	503.66[d]	393.00	378.60	366.60	379.40[d]
Njalipoovan	421.33	408.00	402.00	410.44[f]	312.33	308.30	304.30	308.30[f]
Karpooravalli	531.00	521.00	520.00	524.22[d]	375.00	371.30	368.00	371.30[e]
Kunnan	497.00	472.30	468.00	479.11[e]	353.00	333.60	326.00	337.50[g]
Kanchikela	392.00	381.00	372.60	381.88[g]	241.00	234.00	228.00	234.30[h]
Poovan	620.00	610.00	603.30	611.11[b]	441.00	421.30	417.00	426.40[c]
Mean*	572.46[a]	558.83[b]	553.23[c]		402.90[a]	390.20[b]	383.50[c]	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT
*Main effect Significant
Interaction effect Significant M_1 – First motnh M_2- Second month M_3 – Third month

Among periods of storage, the tensile strength was maximum during first month of storage 402.90 cN/tex, which gradually declined to 390.20 cN/tex and 383.50 cN/tex during second month and third month respectively.

4.3.5 Elongation of plait (per cent)

The results obtained for elongation for banana fibre plait are given in Table 22. Data indicated that elongation varied significantly between varieties. Periods of storage dose not show any significant variation.

The varieties like Kanchikela registered maximum elongation (28.26 per cent) followed by Karpooravalli and Kunnan. Minimum was recorded by Robusta (15.17per cent), which was on par with Palayankodan.

4.3.6 Elongation of rope (per cent)

As can be observed from Table 22, the varieties and period of storage varied significantly for elongation property of rope, made of extracted banana fibre.

In the case of rope also variety Kanchikela recorded maximum elongation of 23.05 per cent followed by Karpooravalli 21.03 per cent. Minimum was recorded by Robusta (12.17 per cent). Periods of storage did not produce any significant difference.

Table 22. Methods of storage and its influence on elongation (per cent) of plaits and ropes different banana and plantain varieties

Varieties	Elongation (per cent)							
	Plaits				Ropes			
	M_1	M_2	M_3	Mean*	M_1	M_2	M_3	Mean*
Robusta	15.26	15.25	15.01	15.17^{d}	12.10	11.86	11.81	11.92^{i}
Nendran	20.99	20.91	20.72	20.89^{c}	18.11	17.92	17.73	17.92^{e}
Monthan	17.26	17.15	17.01	17.14^{d}	13.13	13.02	12.73	12.96^{g}
Palayankodan	17.32	17.11	17.00	17.14^{d}	13.00	13.03	12.91	13.05^{g}
Red Banana	19.31	19.12	19.03	19.15^{c}	16.06	15.76	15.46	15.76^{f}
Njalipoovan	16.35	16.03	16.00	16.13^{d}	12.31	12.11	12.08	12.17^{h}
Karpooravalli	24.38	24.14	24.00	24.18^{b}	21.15	21.02	20.92	21.03^{b}
Kunnan	23.27	23.18	23.04	23.16^{b}	20.16	20.07	19.84	20.25^{c}
Kanchikela	28.41	28.24	28.13	28.26^{a}	23.13	23.12	22.92	23.05^{a}
Poovan	19.50	19.40	19.30	19.40^{c}	19.54	19.34	19.31	19.39^{d}
Mean	20.87	20.26	20.14	Mean*	16.89^{a}	16.73^{b}	16.57^{c}	

In a column and row, means followed by common letter do not differ significantly at 5 per cent level by DMRT

*Main effect Significant

Interaction effect Significant M_1 – First motnh M_2- Second month M_3 – Third month

DISCUSSION

V. DISCUSSION

For thousands of years, mankind has been strongly dependent on plant fibres for all kinds of purposes. The development of synthetic materials (Eg. Plastics) at the beginning of the 20 th century has caused steady replacement of bio- based products. As a result of this change in raw material utilization, combined with enormous increase in energy and chemical demand, the world is now facing an ecological crisis. This necessitates the use of renewable resources at the expense of non- renewable resources.

Among the fibre yielding crops, commercial exploitation is being done for coir alone in Kerala. Banana, the commercial fruit crop of the state is also a very good source of natural fibre. Banana plant, the stem of which consists of layers of thick sheaths wrapped around each other is rich in fibre. The fibre is extracted from sheath and is classified as leaf fibre.

Fibre extraction and conversion into products are being done in a limited scale in the state and so the majority of the pesudostems are being wasted. Scientific investigations for utilisation of banana fibre are very few in the country.

Under this context, the study entitled "Scope of banana and plantain pseudostem sheaths for fibre extraction and its utilisation" was taken up mainly to suggest possibilities of eco-friendly ways of utilization of banana fibre. This helps to increase the income of the banana growers and also provides more employment opportunities particularly to women living in rural villages.

The research programme was conducted through three experiments, the results of which are discussed below.

5.1 METHODS OF EXTRACTION OF FIBRE

Several varieties of banana and plantain are cultivated in the country. The plant grows upto a height of 350 cm. The plants are cut down as soon as fruits are harvested and then psedostems are used for extraction of fibre. Both stems and the ribs of leaves contain very good quality fibre of considerable length. Millions of stems which are at present left to rot can be used for extraction of fibre and then into high utility degradable articles such as cloths, paper and cordages, which are totally eco-friendly.

Out of 20 to 25 sheaths available in a banana pesudostem, the outer 4 to 6 sheaths yield coarse fibre, the inner 6 to 8 sheaths yield soft lustrous fibre and the rest, excluding the inner most 4 to 6 sheaths, yield very tender fibres. Prior to the extraction of fibre, the sheaths should be separated according to the classification as above to separate fibre of more or less uniform quality.

After classification of sheaths, fibre was extracted by three methods viz., hand, machine and after retting.

5.1.1 Hand extraction

The hand method of fibre extraction consists of drawing the strips or tuxies when they are still fresh and succulent, between the edge of a knife and a hard smooth, wooden block attached to a light frame made of rattan canes. The knife usually has serration, in its edge and the number of serration in the knife varies from 0 to 50 per cm. It plays an important role in quantity and quality of fibre. More numerous the serrations the greater the pressure which is put on the tuxie, the finer will be the fibre produced but the lower will be the yield. The fewer the serrations per cm of the knife blade, the greater the quantity of fibre produced. The smallest quantity of fibre and highest quality of fibre depends on the presence or absence of serrations in knife respectively.

In the present study, the fibre extracted under hand method recorded less wet weight (10.53g), less dry weight (4.24g) and percentage of recovery (0.43per cent) compared to machine extraction. This would be possibly attributed to the fact that hand extraction is a laborious work and only a small quantity of fibre could be produced per man per hour. Owing to the hard nature of the work, most strippers only work four or five days in a week. Hence, out put is only 500 g in a day of eight working hours.

5.1.2 Machine extraction

The second method employed for the extraction of fibre is machine extraction. The machine (Raspador) consists of a rigid frame on which a roller drum rotates. The roller consists of horizontal bars with blunt edges. The roller is connected to one HP motor by belt pulley mechanism. The machine is driven by single-phase electric motor. Safety precautions like pulley guards are incorporated in the machine.

In the present study, machine extraction method showed its superiority through its maximum production in wet weight (11.02g), dry weight (4.69g), percentage recovery (0.51per cent) and length (79.3cm). This may be because in machine extraction, the outer most, outer, inner and innermost sheaths were dealt with separate group of machine with the knives of adjustable clearance gap. By this way each group of sheaths was given the best suited pressure to it. Similar study was reported by Andes (1998).

Hand extraction process is a cumbersome work. Being highly laborious only small quantities of fibre can be produced which in turn reduce the total recovery. In hand extraction the sheaths were initially cut into length of 100 cm and a width 6 to 10 cm, whereas, the size of the sheath fed to the machine can be much longer resulting in longer fibre. Machine reduces drudgery, gives clean working atmosphere and clean hands, and with more fibre yield compared to manual method.

However, visual quality of fibre was maximum (27.2) under hand extraction. This would be due to the fact that higher the pressure put on the knife, lower the quality and higher the yield in hand extraction. On the other hand pressure exerted by machine over sheaths in machine extraction were more which in turn would have reduced the quality (Galang, 1995). Another practical difficulty observed in the study was that under machine extraction when sheaths were fed, it could not remove all the tuxies. The fibre obtained contained a lot of pith tissue attached to fibre here and there. This was further refined by using hand extraction. Thus, even now a purely mechanised system of fibre extraction is not yet standardised for banana fibre extraction. Presently the machine greatly reduces the drudgery of work.

5.1.3 Retting

Retting has been defined as "the separation of fibre bundles from the cortex" effecting partial digestion on the cementing material between the fibres in the bundles. Retting is a process by which fibres are separated from bark due to removal of pectin, gum and other mucilaginous substances by retting fungi or bacteria present in water (Singh, 1979). The loosening fibre bundles are also due to the removal of various cementing tissue components presumably of a pectic nature.

In this study, the selected plantain variety Nendran was cut into sheaths of size 40 cm length and treated with retting agents viz., sodium chloride, sodium hydroxide, hydrogen peroxide, sodium hypo chlorite, at a concentration of two per cent, each along with water and on unretted control. *Trichoderma viridae* culture at 40 g of culture mixed with 20 litres of water also served another treatment. The results obtained revealed that among retting agents, sodium hydroxide (two per cent) produced maximum wet fibre (12.22g) and dry fibre (6.50g) followed by hydrogen peroxide. This could be due to the fact that sodium hydroxide reduces dynamic molecules with the removal of lignin and resulted in improvement in fibre yield. Over retting destroyed the strength of fibre and under retting made the fibre coarse and harsh. The major disadvantage of this method was that that it took longer time and fibre produced was of poor lustre due to action of chemicals (Singh, 1979).

5.1.4 Recovery percentage

With uniform sheath weight for all varieties tested, the recovery percentage results revealed that Nendran, Red Banana and Palayankodan recorded maximum percentage. The fibre filaments were cemented together and broke together almost instantly where pressure was applied. So even at under maximum pressure, there was no breakage on the fibre and wastage was minimized. This, in turn, contributed maximum recovery percentage. But in case of Kanchikela and Kunnan, the fibres were more free, the edge break was not spread over the entire length. So breakage occurred often at the time of extraction and reduced the yield (Kundu, 1995).

5.1.5 Wet fibre yield (g)

The fibre yield of varieties varied according to the sheath from which it was taken, stage of maturity of plant when the fibre was extracted and the position of the sheath. In the present study varieties Red Banana and Palayankodan yielded maximum fibre under both methods of extraction (16.5g and 15.8g and 25.7g and 14.5g respectively). This was closely followed by Nendran with the yield of 13.45g and 10.2g. The maximum yield in these varieties might be due to maximum number of inner sheaths ranging from 4 to 5 and increase in sheath weight ranging from 1210g to 1270 g. This is in conformity with the findings of Suma *et al.* (2002) who observed maximum yield in Red Banana and Palayankodan.

The varieties Kanchikela and Monthan produced minimum yield of 6.1g and 6.96g respectively. It could be probably because of production of sheaths of less weight ranging from 800 to 900g. These findings were supported by Mukherjee and Radhakrishna (1999).

5.1.6 Dry fibre yield (g)

Dry fibre yield was also maximum (6.3g and 13.0g respectively) under both the methods of extraction in Red Banana. It showed that moisture loss influence the dry fibre yield.

Among other varieties there was no correlation between wet fibre yield and dry fibre yield. Palayankodan which recorded the second highest (15.89g) wet fibre yield was the least (1.95g) producer of dry fibre. Monthan which recorded the least (6.96g) wet fibre yield gave high dry fibre yield (5.37g). This shows that moisture loss significantly influences the yield of dry fibre among banana varieties and also indicate that initial moisture content of fibre vary from variety to variety. Further detailed studies are required on this aspect.

5.1.7 Length of fibre (cm)

One of the criteria for judging the quality of fibre is the length of fibre. Length of fibre was maximum (94.2cm) in Red banana. This was on par with varieties like Nendran, Karpooravalli and Palayankodan. This could be possible due to presence of large amount of pulp content, surrounding a single filament that remain cemented together and broke almost instantly when pressure was applied. There was no slippage among the cells and the spread of break load was uniform to all the component cells. Similar studies by Kulkarni (1998) in pineapple stated that increase in pulp content reduced the slippage of cells and the same support the present study. Mandal and Roy (1973) have also reported that varietal variation could contribute to the final length of fibre.

Shorter length was recorded by varieties like Njalipoovan (76.2cm), Karpooravalli (72.8cm) and Monthan (74.4cm). The shorter length in these varieties could be possibly due to less pulp content which inturn made fibres more free. With minimum stress the cells of fibre got split out and edge break was spread over the length and ultimately reduced the length of individual fibre.

5.1.8 Visual quality

The visual quality of fibre contributed a great extent the appearance of final produce. The colour and lustre are important parameters with respect to visual quality. The fibre varied in quality according to the variety from which it was obtained and the stage of maturity of the plant and position of sheath. In the present study varieties like Palayankodan and Poovan (Rasthali) recorded the maximum quality. This may be attributed to the fact that high water content of the pulp facilitated the easy extraction of clean fibre from the sheaths. The poor visual quality of Red Banana fibre may be due to red pigmentation in pseudostem, which imported tinge to the fibre, which was unfavourable.

5.1.9 Anatomy of banana fibre

The physical methods determine only the quality of raw fibre and / or products with the help of instruments. Anatomical structure and their variability in different fibres may explain their quality performance and durability. In the study of anatomy of fibre, thickness, lumen width and fibre wall thickness were observed. Among varieties Palayankodan recorded the maximum fibre thickness (47.7 μm). There was variation among banana varieties for anatomical characters. However, Palayankodan has maximum fibre wall thickness (4.4μm) and lumen width (38.09μm). This is due to large fibre cells associated with the xylem which have wide lumen and thin fibre wall as reported by Kirbi (1999). On the basis of anatomical study it could be possible to predict the quality of other fibre crops also. The fibres with less fibre wall thickness is prefered as textile fibres (Singh, 1979).

5.2 STANDARDISATION OF STORAGE METHODS FOR BANANA AND PLANTAIN FIBRE

In Kerala Nendran banana bunches are in heavy demand during August to September for the celebration of Onam, the state festival. Maximum number of bunches are harvested during this period. This is the ideal time for fibre extraction since pesudstems are abundantly available all through the state. But value addition to fibre has to be a year round continuous process decided by market demand. Hence there is a need for proper storage of fibre without deterioration in its quality.

In the present, study fibre extracted from five selected varieties under hand and machine methods of extraction were stored under nine storage treatments over a period of five months. Under the storage study the physical parameters like tensile strength, elongation and density were evaluated.

5.2.1 Comparison of varieties

5.2.1.1 Tensile strength (cN/tex)

The tensile strength is a measure of maximum load, which the fibre can withstand under the very restrictive conditions of uniaxial loading. This value bear direct relation with strength of the fibre, which is useful for the purposes of specification and for quality control of a product. In the present study tensile strength of fibre varied significantly between the varieties. Among the varieties, Robusta recorded the maximum tensile strength (76.8), which was 25 per cent more than Nendran, 32 per cent more than Palayankodan, 29 per cent more than Red Banana and 10 per cent more than Poovan (Rasthali). The proximate components of fibre like hemicellulose and lignin were comparatively less in Robusta and Poovan compared to other varieties. This would have ultimately lead to fibre being more free, which in turn reduced the length of the fibre slipping out of the cells and increased the tensile strength. This is concurrent with the findings of Ganguli and Aditya (1999).

The high tensile strength exhibited by banana fibres indicates its resistance to wear and tear, thus facilitating its use in fabrics, paper manufacture and natural fibre composites, utility bags and so on where strength is main criterion. Further this indicates that varieties can be classified according to their tensile strength and fibres from each class could be put into different end uses. This is very much relevant in Kerala, where a polyclonal situation exists in the case of banana and plantain.

5.2.1.2 Elongation (per cent)

Elongation is qualitative, subjective property of a fibre. In general, it indicates the extend to which fibre can be deformed with out fracture. A high elongation indicates that the fibre is "forgiving" and likely to deform locally with out fracture. Its measurements may be specified to assess the material quality. Eventhough no direct relationship exist between the elongation measurements and performance in service, in the present study, it was observed that variety Red Banana recorded the maximum elongation (6.38per cent) followed by Nendran (5.21per cent) and minimum (1.56per cent) was recorded by Robusta. The variety Robusta which recorded lowest elongation was maximum for tensile strength and varieties Red banana, Poovan (Rasthali) recorded minimum value for tensile strength.

This inverse relation of increasing elongation and decreasing tensile strength could be attributed to the fact that fibres present in varieties like Red Banana and Nendran are highly cemented together so all the fibre cells shared the breakage load and also passed it to the end of the fibre when stress was applied. So there was no breakage in the fibre and we got maximum elongation and reduced tensile strength under these varieties. This is concurrent with the findings of Ganguli and Aditya (1999).

5.2.1.3 Density(g/cm³)

The parameter, density did not show any significant variation between varieties. The density was directly proportional to elongation and inversely proportional to tensile strength.

5.2.2 Comparison of methods of storage

Nine storage methods were tried in five different varieties of banana fibre. The results obtained revealed that the different storage method differed significantly. Irrespective of varieties, fibre stored in HDPE cover without vacuum recorded the maximum tensile strength, minimum of elongation and density in Robusta. The superiority of HDPE cover over other storage method was because of its high heat distortion temperature, superior mechanical and physical properties. This was closely followed by 700gauge polythene bag.

The fibre stored under control (open storage) recorded had the lowest tensile strength among all varieties. It was evident by the exposure of fibre to the open environmental conditions, which facilitated absorption of moisture, microbial and abiotic degradation and it ultimately destroyed the quality.

The parameters, elongation and density did not have significantly influenced by storage. The elongation value ranging from 6.28 per cent to 1.50 per cent was observed under this method. The parameter, density was also not significantly influenced by storage method. However, maximum density ranging from 2.05 per cent to 1.91 per cent was observed under the fibre stored in HDPE covers. For both the above characters minimum elongation and density was observed under control. The results indicated that, HDPE cover could be recommended for storing banana fibre without much quality deterioration upto five months.

5.2.3 Storage stability of fibre over a period of five months

Banana fibres extracted under different methods of extraction were stored under different package/condition for a period of five months. Irrespective of storage method tensile strength, elongation and density varied significantly over a period of five months for five varieties Robusta, Palayankodan, Poovan, Red Banana and Nendran. The tensile strength, elongation and density were maximum during first and second month. Reduction in tensile strength, elongation and density was observed during third month, which further remained stable up to fifth month.

5.3 ASSESSMENT OF SUITABILITY OF BANANA FIBRE FOR PLAITING AND ROPE MAKING

The two important use of banana/plantain fibre are for plaiting and rope making. Hence a preliminary assessment of physical properties of fibres after plaiting and rope making was done.

5.3.1 Water absorbability of plait and rope (per cent)

Water absorbability is an important phenomenon to judge the quality of fibre. The extracted fibre was made into plait and rope and subjected to water dipping treatment. In general, plaits were made by binding the fibres together and in rope making, the fibres were adhered to each other and rolled after twisting.

Among varieties, Palayankodan (241.80per cent) and Poovan (200.00per cent), which are on par with Nendran and Monthan, are observed in plaited sampled. Same result was observed in rope also. However, water absorbability in plait was maximum ranging from 169.62 to 168.25 per cent, whereas in case of rope the water absorbability was less than the plait ranging from 133.10 to 133.97 per cent.

High water absorbability would helpful in dyeing process. Futher, some of the plant fibres have the potential to absorb heavy metals and the fibres with high water absorbability can be used for pollution control in areas where soil has been contaminated with heavy metals. This aspect also requires further investigation.

5.3.2 Tensile strength (cN/tex) and elongation (per cent) of plait and rope

These are the essential physical parameters of fibre which are used for making article like toys, plates, cards, hand bag, purses and so on.

Tensile strength was maximum in Robusta (675.77 cN/tex) followed by Nendran (672.40 cN/tex). So these varieties can be recommended as good for making cordage either alone or also mixed with other fibres. It can be used for other industrial purposes also. On the other hand, Kanchikela which recorded lower tensile strength can be recommended for making ordinary utility items like table mat, pen box purses and so on.

Elongation was observed maximum value in Kanchikela (23.09 per cent) followed by Karpooravalli (24.00 per cent) and minimum in Robusta (15.10 per cent). The variety with maximum elongation can be recommended for making articles, which accommodate more deformation of the structure of fibre like bags, nets and so on.

5.4 FUTURE THRUSTS

- Screening all commercial banana varieties for fibre yield, recovery percentage, physical and chemical properties.
- Standardisation of agronomic practices for improving fibre yield and the effective methods of harvest and fibre extraction by introducing portable machines which help in fibre extraction *in situ*.
- Developing of user (women) friendly methods for mechanised fibre extraction and product making on commercial basis.

- Value addition and product diversification and assessment of economics of fibre production and utilisation.
- Extension programme to popularize the bio degradable banana fibre products as a substitute for non degradable plastic products.
- Creation of awareness about the potential of fibre industry and their environmental benefits by labeling as eco-friendly products to enhance consumer demand and identification of domestic and overseas markets for fibre and their products.
- Studies on further value addition of waste of fibre extraction for vermiculture, composting and so on.

SUMMARY

VI. SUMMARY

Studies on the "Scope of banana and plantain pseudostem sheaths for fibre extraction and its utilization" was carried out in College of Horticulture, Department of Processing Technology, Kerala Agricultural University, Vellanikkara from February 2003 to August 2004. The objective of the study was to asses the suitability of banana and plantain pseudostem sheaths for fibre extraction, the effect of different packages/containers on storage of banana fibres over a period of five months and also assess the feasibility and durability of plaited banana fibre and banana ropes for useful purposes.

The results of the present investigations are summarised below.

1. The maximum wet fiber yield was recorded by Red Banana (16.5g) in hand extraction, In machine extraction also Red Banana recorded maximum (25.7g) wet fiber yield. Under different methods of extraction on wet fibre yield, machine extraction was superior (11.02g) compared to hand extraction (10.53g).
2. In the dry fibre yield production under hand extraction, Red Banana gave maximum yield of 6.3g. In machine extraction also Red Banana recorded the maximum (13.0g). The dry fibre yield was maximum (4.69g) under machine extraction compared to hand extraction (4.24g).
3. The percentage recovery of banana fibre was maximum in Nendran under both the methods of extraction.
4. The variety Red Banana recorded maximum length of fibre under both the methods of extraction. In hand extraction the length of fibre was high (85.3cm) compared to machine extraction (79.3cm).
5. The cellulose and lignin content under hand extraction of Nendran was maximum (62.0 per cent and 11.0 per cent respectively) when compared to machine extraction.
6. Among different retting agents tried sodium hydroxide (two per cent) recorded the maximum (12.2g) wet fibre yield but hydrogen peroxide

(two per cent) was maximum (6.54g) in dry fibre yield and sodium hydroxide (two per cent) recorded the maximum (81.20per cent) for recovery percentage.

7. In machine extraction Poovan (Rasthali) and Palayankodan recorded high total score for visual quality (38.0) value. Under hand extraction Poovan and Palayankodan recorded high (41 and 40) respectively. Among the methods of extraction, hand extraction was rated best (27.2).
8. The maximum fibre thickness (47.7μm) and lumen width (38.0μm) was recorded by Palayankodan and maximum (5.4μm) fibre wall thickness was recorded by Njalipoovan. When the fibre cells were anatomically examined.
9. Under different methods of storage of fibre in Robusta HDPE cover without vaccum recorded the maximum (76.81cN/tex) tensile strength. Mean tensile strength was maximum (67.93cN/tex) in first month after storage (M_1).
10. Fibre stored in HDPE cover without vaccum recorded the maximum (56.54cN/tex) tensile strength and in storage, and second month recorded maximum tensile strength of 50.88cN/tex and 50.56cN/tex respectively.

11. Banana fibre stored under HDPE cover without vaccum recorded the maximum tensile strength (51.32cN/tex) in Palayakodan (Mysore) and first month and second month after storage recorded the maximum tensile strength (48.40cN/tex and 48.18cN/tex) respectively.

12. The treatment HDPE cover without vaccum recorded the highest tensile strength (67.78cN/tex) and was superior to other storage methods. The months after storage M_1 and M_2 were each other with the values of 61.65cN/tex and 61.42cN/tex respectively in variety Poovan.

13. Among storage methods, HDPE cover without vaccum was superior with the maximum tensile strength of 47.62cN/tex in Red Banana. The tensile strength of Red Banana recorded the highest (43.27cN/tex) during first month of storage.

14. Among different storage methods, HDPE cover without vaccum significantly recorded the maximum (6.38 per cent) elongation. With respect to the months after storage, first month recorded maximum (5.82 per cent) elongation. The treatment under HDPE cover without vaccum over a period of one month after storage recorded maximum (6.51per cent) elongation.

15. Fibres stored under HDPE cover without vaccum recorded highest (4.79 per cent) elongation. In storage methods first month recorded the maximum (4.29 per cent) elongation. Maximum value was recorded in HDPE cover without vaccum over a period of five months in variety Nendarn.

16. Banana fibre stored under HDPE cover without vaccum produced maximum (3.72 per cent) elongation in variety Rebd Banana.

17. The elongation of banana fibre in variety Poovan (Rasthali) recorded the highest (5.21per cent) value under HDPE cover without vaccum but in storage, first and second months recorded maximum elongation of 4.53 per cent and 4.48 per cent respectively.

18. Banana fibre stored under HDPE cover without vaccum recorded the maximum (1.56 per cent) elongation. The fibre stored under first month storage significantly recorded the maximum (1.38 per cent) elongation.

19. The maximum fibre density and its retention was recorded by Nendran ranging from 2.24 g/cm^3 to 1.61 g/cm^3 over a period of five months storage.

20. The water absorbability of plait made of banana fibre was maximum (241.48 per cent) for Palayankodan and for time period of storage, first month was found to give maximum (169.62 per cent) absorbability.

21. The water absorbability of rope made of banana fibre of Palayankodan was maximum (204.13per cent) and over a period of three months storage did not show any significant variation.

22. The Tensile strength of plait was high in Robusta (657.70cN/tex) and over period of storage, first month recorded the maximum value for (572.46cN/tex) tensile strength compared to other months.

23. The Tensile strength of rope was high in Robusta (468.60 cN/tex) and among time period, the tensile strength was recorded maximum during first month of storage 402.90 cN/tex compared to subsequent months.

24. With respect to elongation behaviour of plait and rope, the variety Kanchikela registered maximum per cent and storage did not produce any significant difference upto three months.

REFEERNCE

REFERENCES

Akin, D.E., Foulk, J.A. and Dodd, R.B. 2001. Enzyme retting of flax and characterisation of processed fibres. *J. Biotech.* 89: 193-203.

Alexander de blas. 2002. *Paper goes bananas. J.Biosci.*29 (6): 670-674. Available: http://www.abc/earthstories/jbiosci/Aug2002/670.Pdf (09 Aug2002)

Andes, I. 1998. Mechanical extraction of Sunhemp. *Econ. Bot.* 61: 1202-1210.

Aroracharu. 1998. Utilization of abaca fibre as industrial raw material. *Workshop on sustainable development and natural fibres for modern technology*, March10 – 17, 2002 (eds. Jason, M.A. and Mathew, A.N.) Phillipines, pp.120-128

Ashby, K.G. 1998. *Banana fibre-present and future.* Bulletin No: 21 Taiwan Agriculture Centre, Taiwan, 26p.

Azer, V.H. 1999. A study on properties of banana pseudostem of non-renewable resource. *Text. Res. J.* 20: 345-347

Becker, M.V. 2001. Preliminary reports on anatomic observation of fibre development in pineapple. *Indian Text. J.* 4: 26-30.

Bhattacharya, S. 2000. New pineapple fibre processing machine. *Text. Prog.* 4: 81-84.

Biswas, S. 2001. Properties of chemical retting of plant fibres. Proceeding of annual conventions and trade show composites, 3-6 October 2001, Florida, USA. *Abstract*: 48.

Biswas, S. 2002. Plant fibre products. *Indian Text. J.* 58: 145-150.

Bose, S.K. 2000. The natural fibers. *Text. Res. J.* 30: 545-547.

Bowlin, G.L., Mathews, J.A. and Simpson, D.G. 2000. Parametric study of electrostatic fibre formation. *J. Appl. Ecol.* 45: 561-570.

Cang, S.R. 1998. Study on characteristics of fibre from abaca and its chemical treatment. *J. Appl. Ecol.* 37: 351-359.

Canning, L. 1995. *Second report on Taiwan paper mills. Womens environment net work.* Bulletin No. 10. Taiwan Agriculture Centre, Taiwan, 40p.

Chand, J. and Hasmi, R. 2000. Anaerobic digestion of banana stem waste. *Bioresource Technol.* 73: 191-193.

Chengowen., Van-onna and Van-den-Ent-Ej. 2001. Sales prospects for banana and banana pulp for the paper industry. *Physiol.pl.Plantl.* 114: 296-302.

Galang, E. 1995. Murva fibres. *Text. Prog.* 24: 6-15.

Ganguli, D.K. and Aditya, M. 1999. The relationship between the fibre strength and its saccharide content. *China Cott.* 20: 12-14.

Ganguly, K.L. 1992. Studies on microbial retting of jute. *China Fibre Crops.* 1: 29-32.

Guo, P.K. and Iwamida, T. 1994. Study on characteristics of fibre from *Anana sativa* and its chemical treatment. *J. Sci. Fd. Agric.* 62: 1-20.

Gupta,V. 1996. The potential of plant fibres as crops for industrial use. *int. Trade Forum.* 27: 10-15.

Hayavadana, J., Jacob, M.D. and Geetha, S. 1998. Diversified product of pineapple leaf fibres. *Text. Res. J.* 24: 301-305.

Heinmann, O. 1995. On-stem retting of flax. Experiences with large scale application. *Land Tech.* 50: 206-207.

Hewawasama, V. 2000. Extracting abaca fibre. *J. Sci. ind. Res.* 26: 6-24.

Idicula, M. 2003. Tensile, flexural and impact properties of banana hybrid fibre composites. Proceedings of 15th Kerala Science Congress, 29 – 31st January 2003, Trivandrum. P. 814.

Indira, G. and Chelamani, P. 1997. Pineapple leaf fibres. *Text. Prog.* 24: 1-37.

Iyer, P.B., Vivekanandan, M. and Srinivasan, S. 1998. Banana fibres: Study and properties of some varieties. *Indian Text. J.* 105: 42-48.

Jeyachandran, K. and Bhatacharya, S.K. 2000. Extracting abaca fibre. *J. Sci. ind. Res.* 24: 4-27.

Kalpana, S. 2003, Feb. 9. Banana fibre emerging good business propositions. *Hindu.* p10.

Kerski, N. 2002. Pineapple leaf fibre. *Indian Text. J.* 104: 76-79.

Kestler, M., Becker, V. and Kohler, R. 2001. Enzyme retting and characterization of processed fibres. *J. Biotech.* 89: 2-3.

Kirbi, S. 1999. Correlation of the physical properties of jute yarn with the chemical characteristics of the fibre. *Bengal Agric. j.* 4:118-122.

Koster, R., Brokeland, L. and Groot, R. 2001. Chelating agents and enzyme retting of flax. *Text. Res. J.* 4: 26-30.

Kulkarni, N.M. 1998. Some physical characters of pineapple plant fibres. *Text. Res. J.* 20: 320-324.

Kundu, B.C. 1995. The effect of maturity on the dimensions of the ultimate fibre of jute. *J. Sci. ind. Res.* 14: 124-127.

Kymalainen, H.R., Hautala, M. and Kuisma, R. 2001. Capillarity of abaca (*Musa textilies*) and fibre hemp (*Cannabis sativa*) straw factors. *ind. Crops Products*. 14: 41-50.

Lahaussois and Kryklund. 2001. Natural fibre composites from upholstery to structural components. *J. Maert. Sci.* 14: 4015 – 4020.

Lancon, D. 1998. Renewable raw materials for Horticulture. *Indian Text. J.* 105: 42-48.

Law, K. N. 2001. Fibre morphology and soda sulphite pulping of musa. *Bioresource Technol.* 77: 1- 17.

Lenz, F.D. 1994. On the elongation mechanism of regenerated cellulose fibres. *Text. Prog.* 37: 24 -28.

Liu-Zhengchu. 1995. A study of factors affecting retting of jute. *J. Sci. Fd. Agric.* 38: 14-26.

Maini, N. 1992. Utilization of by products from the tequila industry: Part. 1. Banana as a raw material for fibreboard production. *Bioresource Technol.* 52: 25 – 32.

Mandal, S.K. and Roy, B. 1973. Some physical characteristics of jute fibre. *Text. Res. J.* 30: 545-546

Margretfrey, 2003, Sep. 4. Turning waste into fibre. *Hindu*. p10.

Martin, F. 2003, Jan. 3. Spinning success out of banana tree. *Hindu*. p10.

Mcdougall, G.J., Morrison, I.M. and Stewart, D. 1993. Plant fibres botany, chemistry and processing for industrial use. *J. Sci. Fd. Agric.* 58: 1-26.

Meijer, R. 1995. Pectin content as a measure of retting and rettablity of flax. *ind. Crops Product*. 4: 273-284.

Mooney, C. 2001. Analysis of retted and non-retted flax fibres by chemical and enzymatic means. *J. Biotech.* 89: 205-216.

Mukerjee, G. 2000. Preliminary report on anatomic observation of stem fibre. *China Fibre Crops*. 4: 26-30.

Mukherjee, S and Radhakrishna, R.T. 1999. On water relations of jute plants. *Bot. soc. Bengal.* 5: 55-63.

Nachane, R.P. and Uma, S. 2001. Processing of banana pseudostem for extraction of fibres. National Academy of Agricultural Sciences, 6 th agricultural science congress. 13-15 February 2001, Bhopal, 254p.

Nair, N. 2004, Feb. 12. Womens society makes good money from banana fibre. *Hindu*. p10.

Nangia, K.N. 2001. Appilication of new parameters for estimating the fibrousness of banana. *ind. Crops Products*. 14: 65-73.

Pallensen, B.E. 1996. The quality of combine harvested fibre flax for industrial purpose depends on the degree of retting. *Ind. Crops Products*. 5: 65-78.

Paul, D., Banik, S. and Mukerjee, A.B. 1998. Extracting pineapple leaf fibre. *Bioresource Technol.* 24: 4 – 7.

Pushkaran, K and Arvindakshan, M. 1996. Banana fibre wealth from waste. Banana compendium, Kerala Agricultural University, Trichur, Kerala, India. 160p.

Ramy-azer,M. 2002. *Paper goes bananas. J.Biosci.*29(6):670-674. Available: http://www.abc/earthstories/jbiosci/Aug2002/670.Pdf(09 Aug2002)

Ranjith, M. 1993. Natural fibre and their composites. *Econ. Bot.* 48: 310-325.

Rao, A. 1999. Geotextiles opportunities for fibre products. *int. Trade Forum*, 13: 10 - 15.

Revathy, L.N. 2002, Feb. 9. Banana fibre emerging good business proposition. *Hindu*. p10.

Satinder, K., Paul, S. and Gupta K.C. 1993. Physiochemical properties of fibre. *Text. Prog.* 24: 1-37.

Shamsul, M. and Haque, M.D. 2001. Retting of green jute ribbons with fungal culture. *J. Biol. sci.* 11: 1012-1014.

Shanmugavelu, K.G., Aravindakshan and Sathyamoorthy, S. 1992. *Banana – Taxonomy, breeding and production technology*. Metropolitan Book co, New Delhi. 454p.

Shivashankar, S., Nachane, R.P. and Kalpana, S. 2002. Composition and properties of psedostem fibre extracted from some commercial varieties of banana. . Global conference on banana and plantain, 28-31 October 2002, association for the improvement in production and utilization of banana, Bangalore. *Abstract*: 201.

Singh, R.K. 1979. *Plant fibres*, Newman and co., Calcutta, 302p.

Sinha, R. 2000. The potential of plant fibres as crops for industrial use. *Outl. Agric.* 24: 85-89.

Srikanth, M. and Datta, P. 2001. Lignin and lignification with special reference to its down regulation for the improvement of fibre quality. *Ind. J. Plant. Physiol.* 11: 217-228.

Sudhakar, K. 2002. *Banana fibre extractor and user-friendly machine*. KAU *Newsl.* 8 (4).

Sulaiman, S. 2001. Chemical retting of flax straw under alkaline condition. *Text. Res. J.* 52: 27-32.

Suma, A., Menon, R. and Cherian, A. 2002. Banana fibre – a swot analysis. Banana fibre utilization – problems and prospects with special relevance to Kerala, KAU, Trichur, Kerala, India. pp24-28

Suma, A., Menon, R., Cherian, A.K. and Nair, S. 2002. Utilization of banana fibre: Problems and prospects with special relevance to Kerala. Global conference on banana and plantain, 28-31 October 2002, association for the improvement in production and utilization of banana, Bangalore. *Abstract*: 202.

Throat, S.S., Marekar, D.B. and Surve, V.D. 1997. *Studies on the some properties of byproducts (fibre and starch of banana pseudostem)*. Bulletin No. 47. Punjab University Science, Punjab. 38p.

Varkey, P.A. and Pushkaran, K. 1992. Banana cultivation. KAU, Trichur, Kerala, India. 54p.

Venkatasubramanian, R. 2003, Mar.7. Low cost fibre technology. *Hindu.* p10.

Yesuvadian, M.S. 1998. Banana fibre. Paper supplied for banana work group meeting, KAU *Newsl.* 6(4)

Yu, C. and Maze, B. 2001. Properties and processing of plant fibre. *China Fibre Crops*. 21: 212-217.

Zang-Yuanming, 2000. Chemical treatment of fibres of *Ananas sativa*. *China Fibre Crops*. 3: 28-37.

Zhang-zing, 2000. Research on pineapple leaf fibre extraction and processing equipments. Transactions of Chinese society of agricultural engineering, 2-3 August 2000, China. *Abstract*: 43.

Zhou, I. 1992. Preliminary study on the relationship between stem shapes, fibre yield and fibre fineness in abaca. *Econ. Bot.* 3: 220-270.

SCOPE OF BANANA AND PLANTAIN PSEUDOSTEM SHEATHS FOR FIBRE EXTRACTION AND ITS UTILIZATION

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ABSTRACT OF THE THESIS

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ABSTRACT

Studies were conducted at College of Horticulture, Department of Processing Technology, Kerala Agricultural University, Vellanikkara from February 2003 to August 2004 to asses the "Scope of banana and plantain pseudostem sheaths for fibre extraction and its utilization". The fibre extracted under hand method of extraction recorded less wet weight (10.53g), less dry weight (4.24g) and percentage of recovery (0.43per cent). In mechanical extraction comparable values with wet weight (11.02g), dry weight (4.69g), percentage recovery (0.51per cent) were obtained. The visual quality of fibre was rated as maximum under hand extraction. In retting method of fibre extraction, among different retting agents sodium hydroxide (two per cent) produced maximum wet fibre (12.22g) and dry fibre (6.50g) followed by hydrogen peroxide (two per cent).

In regard to wet fibre yield, varieties Red Banana and Palayankodan yielded maximum fibre under both methods of extraction (16.5g and 15.8g and 25.7g and 14.5g respectively). Dry fibre yield was also maximum (6.3g and 13.0g respectively) under both the methods of extraction in Red Banana. The recovery percentage results revealed that Nendran, Red Banana and Palayankodan were showing higher percentage due to increase in sheath weight. Length of fibre was maximum (94.2cm) in Red banana. In visual quality assessment Palayankodan and Poovan (Rasthali) varieties recorded the superiour quality fibres. Palayankodan exhibited maximum value for fibre wall thickness (4.4µm), fibre thickness (47.7 µm) and lumen width (38.09µm)

Among the varieties, Robusta recorded the maximum tensile strength (76.8), which was 25 per cent more than Nendran, 32 per cent more than Palayankodan, 29 per cent more than Red Banana and 10 per cent more than Poovan (Rasthali). The variety Red Banana recorded the maximum elongation (6.38 per cent) followed by Nendran (5.21per cent) and minimum (1.56 per cent) was recorded by Robusta. The density of fibre was directly proportional to

elongation and inversely proportional to tensile strength. The density was maximum (2.05g/cm^3) for Nendran and minimum (1.78 g/cm^3) for Palayankodan. Irrespective of varieties, fibre stored in HDPE cover without vacuum recorded the maximum storage stability for tensile strength and minimum of elongation and density in Robusta. Irrespective of storage method tensile strength, elongation and density of fibre varied significantly over a period of five months in respects of varieties viz., Robusta, Palayankodan, Poovan, Red Banana and Nendran. The stability of tensile strength, elongation and density were maximum during first and second month. The water absorbability in banana fibre plait was maximum ranging from 169.62 per cent to 168.25 per cent, whereas in case of rope the water absorbability was lesser than the plait ranging only from 133.97 per cent to 133.10 per cent. Tensile strength was maximum in the plait of variety Robusta (675.77 cN/tex) and elongation was observed to be maximum in Kanchikela (23.09 per cent).

APPENDIX

Mean values of different characters of fibre under different methods of extraction (g)

Sl.No	Character	Hand extraction (g)	Machine extraction (g)
1.	Sheath weight	970.85	959.8
2.	Wet fibre yield	10.53	11.02
3.	Dry fibre yield	4.24	4.69
4.	Recovery from wet fibre yield	40.8	45.7
5.	Recovery from Sheath weight	0.43	0.51