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UTILIZATION OF PINE NEEDLES

Part I. Extraction of pine fibres and their physical and chemical characteristics

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Pine needles of Chir pine (*Pinus roxburgia*) were collected from Batrasi forest area. A chemical method has been developed for the extraction of pine fibres. Physical properties of pine fibres such as linear density, strength (dry, wet), tenacity, tensile strength, ultimate fibre diameter and length were determined. Moreover, chemical composition of the fibres such as cellulose, lignin, extractives, moisture and ash were also determined. The properties of pine fibres were compared with other vegetable fibres for assessing the end uses.

INTRODUCTION

Vegetable fibres have been playing a significant role in textile production. The most prominent amongst them is the cotton fibre which belongs to the group of seed fibres. The other vegetable fibres of commercial importance are jute, flax, ramie, sisal, abaca, sunnhemp and kenaf. Jute and flax are among the leading fibres of the category of bast fibres which contribute extensively to the textile industry [1].

Pine needles, abundantly available in the country as an indigenous waste material, can be obtained in constant supply round the year, but are not being utilized, although their presence as such in the forests may be hazardous. An attempt was, therefore, made to explore the possibilities of utilizing pine needles as a source of vegetable fibre. The fibres (technical as well as ultimate) were tested for their physical and chemical characteristics for comparison with other commonly used vegetable fibres.

MATERIALS AND METHODS

Pine Needles. Various types of pine needles are available is North West Area of Pakistan. Pine needles from "Chir pine" (*Pinus roxburgia*) were used in the present study. Dried mature needles of dark brown colour which had fallen on the ground were collected from the Batrasi area of Hazara district. These needles ranged from 6–10 inches in length and were longer than needles from other pine species.

Production of Pine Fibre. Usually retting methods are employed for extraction of vegetable fibres, but in the present studies retting process could not be applied as the pine needles are very hard. Following chemical process was, therefore, devised for the extraction of pine fibre from pine needles:

Pine needles were boiled with 4% NaOH for 30 min. After the alkaline treatment, the needles were gently beaten with wooden hammer and washed thoroughly to remove completely the last traces of alkali. When the needles were half dried, they were rubbed with hands to fully relieve the fibre bundles from the adhering cellular tissues. Finally the fibres were combed. The fibres obtained by this method were dried at room temperature. These fibres were brown in colour. 5g samples were taken at random for determining the physical and chemical characteristics.

METHODS

(i) *Measurement of Linear Density.* The length of pine fibres (bundle) was measured by stretching the fibre along a metre rod and recording the distance between the two ends. The ultimate fibres were separated and their dimension measured by the methods of Maiti and Basu [2]. The ratio of length to diameter (Linear density) was determined for bundle as well as ultimate fibre.

(ii) *Diameter Measurement.* Diameter of 100 fibres (ultimate and technical) from each sample was determined by the common method of inserting fibre slides in the projection microscope(Ianameter)of X 500 magnification[3].

(iii) *Measurement of Strength and Elongation.* The strength of the fibres was determined by a pendulum type tensile testing machine running on a constant rate of traverse principle. Thirty fibres from each sample were

measured for strength and elongation. The strength and elongation of wet pine fibres were determined by the same procedure except that each fibre was kept in distilled water for 24 hr at room temperature before mounting on the strength tester. The readings were taken at "standard atmospheric" condition.

(iv) *Chemical Composition of Pine Fibres.* Cellulose was determined by known chlorination method of Cross and Bevan [4], and lignin by the method of Ellis and Coworkers [5]. Extractives, moisture and ash were determined by the usual procedures.

RESULTS

The results of fibre length, linear density and fineness of pine fibres are recorded in Table 1. Table 2, shows fibre fineness, strength, elongation, tenacity and tensile strength of individual pine fibres. In Table 3 are presented the values of fibre fineness, strength, elongation, tenacity and tensile strength of the pine fibre (bundle). The results of strength and elongation of the dry and wet fibres have been shown in Table 4. The diameter and length of the ultimate pine fibres have been recorded in Table 5.

Chemical analyses of the fibres are given in Table 6. Comparison of the chemical constituents of pine fibres with the known and commercially established vegetable fibres have been made in Table 7. The physical characteristics of pine fibres have been compared with the known fibres of vegetable origin. This has been shown in Table 8.

DISCUSSION AND CONCLUSIONS

Table 1 shows the fibre length, linear density and fineness of 17 samples of pine fibre. The fibre length varies from 9 to 21 cm, with a mean value of 15.5 ± 3.6 cm, longer fibre length cannot be obtained as the pine needle length ranges from 15 to 25 cms. Table 1 also shows the linear density which is the weight per unit length and provides useful general way of describing the fineness or coarseness of yarn. But a better way of describing fineness is denier system, because this unit is used when the results are compared with other type of fibre later on. From Table 1 it is evident that there are large variation in fineness (range from 81 to 123 denier), mean being 102 denier.

In Table 2, the strength characteristics of individual pine fibres are given. The fineness of fibres is expressed in micron and denier systems. The tenacity is expressed in g/denier. The range of fibre diameter is between 145–165μ. mean value = 153.7 μ. The variation in the fineness of the fibres once again confirms that the fibres are uneven and this will consequently give rise to uneven yarn formation.

Table 1. Mean fibre length, linear density and fineness of pine fibres.

Sample No.	Length (Cm)	Weight (mg)	Linear density μg/cm.	Fineness denier 1
1.	18.9	2.20	116	104
2.	20.8	2.40	115	104
3.	19.2	2.25	117	105
4.	17.8	2.10	118	106
5.	21.2	2.33	110	99
6.	19.3	2.38	123	111
7.	15.9	1.43	90	81
8.	20.5	2.49	121	109
9.	18.1	1.90	105	95
10.	17.1	1.80	105	95
11.	10.3	1.13	109	98
12.	13.4	1.40	104	94
13.	9.1	1.06	116	104
14.	10.4	1.26	121	109
15.	10.9	1.50	137	123
16.	11.5	1.25	108	97
17.	9.9	1.15	116	104
Mean	15.5	1.76	114	102
S.D.	5.84	–	13.58	9.10
S.E.	1.85	–	4.299	2.88
CL(95%)	± 3.62	–	± 8.43	± 6.8

The variations in the strength values of pine fibres are greater as compared to fineness and other strength characteristics. The mean value is 58.7 ± 10.2 g. The Table also shows values for elongation, tenacity and tensile strength of the fibres. The elongation varies between 2-4% and the average elongation 2.9 ± .52%. The presence of elasticity or elongation in vegetable fibres helps in the spinning process. The tenacity of these fibres varies between 0.18 – 0.32 g/ denier. (mean value = 0.24 ± 0.04 g/ denier). This shows the weight of yarn of a definite length and as such this will also give indication of the quality of end product. The values of tensile strength of fibres as well as the mean value 2.94 ± .53 kg/mm^2 are shown in the last column of the Table. There are no relationships between breaking strength and diameter or area of cross section in the case of pine fibres. This is not in accordance with Stout and Jenkin's observation who have shown that the breaking strength of bast fibres increases as the area of cross section decreases [6].

Table 3 contains the mean values of strength characteristics of pine fibres (bundle). The variation patterns of the mean strength, elongation, tenacity and tensile strength

Table 2. Strength characteristics of individual pine fibre.

Fibre No.	Fineness (Denier)	Diameter (micron)	Strength (g)	Elongation %	Tenacity g/denier	Tensile strength kg/mm^2
1.	245	152.8	44	3.1	0.18	2.38
2.	241	151.6	50	2.0	0.21	2.76
3.	286	165.0	65	3.1	0.23	3.03
4.	248	153.8	73	2.0	0.30	3.91
5.	254	155.4	80	4.1	0.32	4.20
6.	243	152.0	75	3.1	0.32	4.12
7.	221	145.2	34	2.0	0.16	2.04
8.	240	151.2	73	4.1	0.31	2.05
9.	255	155.8	41	3.1	0.17	2.14
10.	249	154.0	52	2.0	0.21	2.78
Mean	248	153.7	58.7	2.9	0.24	2.94
S.D.	16.3	4.96	16.42	0.835	0.065	0.852
S.E.	5.16	1.56	5.19	0.264	0.020	0.269
Cl(95%)	± 11.2	± 3.1	± 10.2	± 0.52	± 0.044	± 0.53

Table 3. Mean values of strength characteristics of pine fibre (bundle).

S. No.	Finesess (denier)	Strength 9g)	Elongation %	Tenacity g/denier	Tensile strength kg/mm^2
1.	309	55.7	3.8	0.18	2.42
2.	305	57.4	4.0	0.19	2.51
3.	275	54.5	3.8	0.20	2.64
4.	243	57.1	3.1	0.24	3.13
5.	265	57.1	3.4	0.22	2.90
6.	239	56.4	3.2	0.24	3.14
7.	230	56.1	2.8	0.26	3.25
8.	248	58.7	2.8	0.24	3.15
9.	244	50.0	3.2	0.21	2.73
10.	253	54.5	3.1	0.22	2.87
Mean	261	55.7	3.3	0.22	2.87
S.D.	27.4	2.39	0.42	0.21	0.29
S.E.	8.7	0.759	0.133	0.006	0.092
CL (95%)	± 18.8	± 1.5	± 0.26	± 0.014	± 0.18

are greater as compared to those of individual pine fibre (Table 2). The range of variation for the values of mean fineness is 230–309 denier (mean 261±18.8 denier). Similarly, strength values vary between 50–57g and the mean strength is 55.7 ± 1.5 g. Similarly, the mean elongation is 3.1% and the mean tenacity and tensile strength are 0.22 ± 0.01 denier and 2.87 ± 0.18 Kg/mm^2 respectively. The variation in fineness in Table 1, 2, 3, may be due to the extrac-

Table 4. Comparison of dry as well as wet strength and elongation of pine fibres.

Fibre No.	Dry Fibres		Wet Fibres		Decrease in strength	Increase or decrease in elongation
	Strength (g)	Elongation %	Strength (g)	Elongation %		
1.	70	5.1	50	9.4	20	+ 4.3
2.	30	2.9	18	3.5	12	+ 0.6
3.	130	3.7	30	5.1	80	+ 1.4
4.	55	3.7	30	8.0	25	+ 4.3
5.	60	5.1	40	6.5	20	+ 1.4
6.	65	5.1	25	5.1	40	0.0
7.	65	3.7	23	2.3	42	– 1.4
8.	57	3.7	26	5.1	31	+ 1.4
9.	52	2.3	18	5.1	34	+ 2.8
10.	90	5.1	40	5.1	50	0.0
11.	45	3.7	26	3.7	19	0.0
12.	35	2.9	22	5.5	13	+ 2.6
13.	70	2.3	26	5.1	44	+ 2.8
14.	106	2.3	52	4.0	54	+1.7
15.	85	3.7	30	3.7	55	0.0
Mean	67.7	3.7	30	5.1	36	1.5

Table 5. Fibre diameter, fibre length and fineness (denier) of ultimate pine fibre.

Fibre No.	Diameter (micron)	Length mm	Fineness (denier)
1.	36.6	12	14
2.	36.2	14	14
3.	27.6	11	8
4.	31.8	15	11
5.	32.4	13	11
6.	34.6	16	13
7.	29.0	14	9
8.	29.4	10	9
9.	34.6	16	13
10.	31.4	12	10
Mean	32.3	13.3	11
S.D.	3.10	2.05	2.21
S.E.	0.982	0.651	0.69
CL (95%)	± 1.9	± 1.3	± 1.5

tion method which produces fibres of varying fineness.

The values of strength and elongation of the pine fibres in dry and wet condition have been presented in Table 4. It is evident from the Table that on wetting, the fibre loses strength, but improves the elasticity. The decrease in strength of the wet fibre is substantially high. At the same time on wetting, the elongation of fibres is increased quite distinctly. The decrease in strength varies from 12 to 80 g. The increase in elongation is between 0 to 4.3%. In the case of four fibres, the increase in elongation is zero and in the case of one fibre there is decrease in the fibre elongation. These abnormalities may be due to the reason that each fibre was cut into two equal portions for determining the dry and wet strength & elongation. Further, it seems that a portion of the fibre may be damaged during the extraction process.

The ultimate fibre diamensions of pine fibres are recorded in Table 5. The diameter of various ultimate fibres varies from 29.0 to 36.6 μ The average diameter is 32.3 ± 1.9 μ. The values of diameter of the ultimate fibre compare favourably with those of hemp and ramie fibres [7]. The mean fineness of ultimate fibre is 11 denier. These values are higher than values of other vegetable fibres except ramie (Table 8). The length of these ultimate fibres ranges from 11 to 16 mm, mean being 13.3 ± 1.3 mm.

The results of chemical analysis of pine fibre have been presented in Table 6. It is evident from the results that the fibres contain 60% cellulose and 17.7% lignin . The mean values for extractive and ash percent is 11.1 and 3.3 respec-

Table 6. Chemical composition of pine fibre.

Sample No.	Cellulose %	Lignin %	Extractives %	Moisture %	Ash %
1.	60.2	18.0	11.2	7.7	3.3
2.	59.5	17.5	11.0	8.3	3.5
3.	60.0	18.5	10.9	8.2	3.2
4.	60.7	18.0	11.7	7.8	3.2
5.	60.5	17.6	11.4	7.9	3.1
6.	58.9	17.2	11.0	6.8	3.3
7.	59.3	18.1	10.8	8.0	3.4
8.	60.2	17.7	10.9	7.6	3.3
9.	60.5	17.5	11.1	7.5	3.0
10.	60.8	17.0	11.4	6.9	3.4
Mean	60.0	17.7	11.1	7.7	3.3

Table 7. Chemical composition of various vegetable fibre, data from literature [1,2].

Fibre	Cellulose %	Hemi-cellulose %	Lignin %	Extractive %	Moisture %	Ash %
Jute	64.4	12-16	11.8	1.4-2.0	9.9	0.68
Flax	64.0	17.0	2.0	6.0-9.0	9.0	1.00
Hemp	67.0	12-16	2.0-3.3	4.0	8.8	0.82
Ramie	68.6	12-16	5.6	6.0	6.4	0.12
Sisal	65.8	13-18	14.5	1.1-2.5	6.2	1.00
Abaca	63.2	19.6	5.1	2.1	6.1	1.00
Kapok	64.0	–	13.0	–	10.0	2.00
Pine fibre	60.0	–	17.7	11.1	7.7	3.3

1. Urquhart & Howitt (1963); 2. Harris Textile Fibres.

tively. The cellulose (%) of vegetable fibres is of significance as it determines the value of fibres for textile use. Generally, the vegetable fibres of bast group contain higher cellulose than that of the fibres of leaf group [8]. Also the lignin content of leaf fibres is higher than that of the bast fibres. Higher lignin percentage imparts yellow colour to the fibres. This shows that the non–cellulosic substances are present in sufficient quantity in the pine fibres. The average moisture is about 7.7% which is quite satisfactory as fibres of lower moisture content are unsuitable for textile purposes, in view of the fact that such fibres are difficult to be spun. Also the dyeing of such fibres is inconvenient [9].

Table 7 contains the precentage results of chemical constituents of various vegetable fibres. The percentage suggests that the pine fibre may be softer than other vegetable fibres mentioned above. Jute and kapok fibres may be slightly softer than the pine fibres. The variation of the ash percentage of pine fibres is much higher i.e. the ash (%) of all other vegetable fibres ranges from 0.1 to 2.0%, whereas, that of pine fibre is 3.3%. This shows the presence of mineral matter in the ash of the pine fibres.

The comparison of the physical properties with the commercial known vegetable fibres has been made in Table 8. The fineness of sisal and abaca show high denier values. They seem to be much higher than required, based on their ultimate fibre dimension. The other figures do fit in very well. The fineness of pine fibres is very high. So it seems to be very difficult to prepare a relatively fine yarn. The tenacity and tensile strength for hemp and ramie are a bit

Table 8. Comparison of results with data from literature [1].

Fibre	Ultimate fibre (denier) (μ)	Ultimate fibre fineness (denier)	Fineness bundle (denier)	Tenacity (g/denier)	Tensile strength (kg/mm^2)	Elongation Dry %	Elongation Wet %	Wet strength (% of dry)
Jute	17.18	3.0-3.4	12-21.4	3.1-3.8	40.6-43.9	1.3	–	–
Flax	16-19	2.7-3.8	1.7-17.8	5.6-6.6	77.0-83.4	1.7	2.2	105.5
Hemp	19-25	3.8-6.6	3.1-20.0	5.2-6.8	84.0-90.3	1.8	–	–
Ramie	40-47	17-23	4.6-6.4	6.5-7.3	90.8-99.0	4.5	2.2	114.5
Sisal	19-21	3.8-4.6	41.8	4.2	44.1	1.9	–	–
Abaca	24	6.0	38.3	4.0	10.8-46.8	2.5	–	–
Kapok	18	3.4	0.6	1.8	–	–	–	–
Coir	20	3.8	–	–	1.8	–	–	–
Pine fibre	32	11.0	242	0.24	2.9	3.1	5.1	44.0

1. Harris Textile Fibre.

low; the other fit in very well. Tenacity, tesile strength and chemical composition of the pine fibres has been compared with other vegetable fibres. The cellulose percentage of pine fibre is comparable with that of the jute, kapok and abaca fibres. The cellulose (%) of ramie and sisal are higher than that of pine fibres. The lignin percentage is also closely comparable to the values of jute, and kapok fibres. The lignin content of sisal fibre is slightly less than that of the pine fibres, whereas, the values of hemp and ramie are much lower than that of pine fibres. The percentage extractive of pine fibre is higher than that of other vegetable fibres. The moisture content of pine fibres is well comparable with all the vegetable fibres except those of jute, and kapok which is higher. The moisture content of pine fibre is slightly higher than ramie, sisal and abaca fibre. This for pine fibre are very low, while elongation is relatively high. Wet strength is also very low. So it is evident that the pine fibre extracted with sodium hydroxide became weak.

Keeping in view the above properties of pine fibres, it is concluded that as such pine fibre could only be used as a cheap filler material, like tow from sisal, or in rags like coir.

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