PHYSICAL CHARACTERISTICS AND UTILIZATION OF AK (*CALOTROPIS PROCERA*) FIBRES

by

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Summary. *Two series of Ak samples, one collected at random from ten different sources at the flowering stage (July), and the other from Peshawar at various stages of maturity, were examined for a number of physical characteristics. A number of different methods of retting were investigated to get at the optimum procedure. The anatomical characteristics, length, diameter and ratio of length to diameter of the ultimate fibres were evaluated. The effects of stage of harvesting, methods of retting, different levels of relative humidity, and anatomical characteristics on the strength of the filaments were examined.*

Introduction. Ak (*Calotropis procera*) is a common wild plant of our plains, ascending to 1300 metres (4, 24). It has fibre in the seed floos as well as in the stem; the former is short but the latter is long and strong. The bast fibres are commercially important (5, 6, 25) and the uses extend from twines to textiles. The fibre when bleached can be spun by itself or mixed with cotton (5). The plant is being cultivated in South America and the Carribean Islands for the floss alone (16). According to Dodge (cf. 25), an acre planted with *C. procera* at 122 × 122 cm. spacing would yield 10 tons of green stems and 264 kg. of fibre with a fibre yield of 2.6%. Also, the plant grows wild over a wide range of climatic conditions.

Although its usefulness had been shown as early as 1852 (24) little data is available on the characteristics of its bast fibres and that too is at variance. Berkman (2) gives a range of 18.75 to 28. 13 mm for the length of its ultimate fibre, while Kirby (9) gives a range of 35-44 mm for the same. Part of this variation may be due to biological and site factors, but a part of the variations in the scanty reports may also stem from the confusion with its sister species *C. gigantea* and the differences in the methods adopted for analysis.

The specific objectives of the present investigations were:

(*i*) To analyse physical and chemical characteristics of the fibre from the bast of Ak (*C. proc era*) indigenous to Pakistan.

(*ii*) To analyse effect of time of harvesting on the fibre characteristics.

(*iii*) To develop a process for extraction of the fibres, keeping in view its economics as well as its effects on the properties of the fibre.

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(*iv*) To analyse the effect of level of moisture on the strength of the fibres, influencing the use of the fibre for fishing and marine purposes.

Materials and Methods. *Samples.* Samples were obtained in two different manners, in accordance with the objectives of the work: In the first approach, samples were collected from 10 different localities in the northern part of the country (within a radius of 200-300 Km.), all at the flowering stage (July)-Series 'A'. In the second approach, ten plants of average growth were selected around Preshawar and sampled at the following stages (Series 'B'):

(*a*) Pre-flowering (March).

(*b*) Early Flowering (June).

(*c*) Flowering (September).

(*d*) Late flowering (December).

Extraction of fibres. The following eight different methods of obtaining fibres were selected for a systemetic examination:

(*a*) Direct extraction without retting or steaming.

(*b*) Retting in clean water for 48 hrs, then steaming and pressing between wooden rollers.

(*c*) Retting in stagnant water for 2-3 days.

(*d*) Retting in slowly flowing water for 3-4 days.

(*e*) Stripping and retting of strips for 2-3 days in a closed tank incorporating 1% Urea.

(*f*) Stripping and retting of strips for 2-3 days in a closed tank incorporating 1% NaOH.

(*g*) Stripping and retting of strips for 2-3 days in a closed tank.

(*h*) Steaming the stalks followed by pressing between wooden rollers.

Based on the results of these investigations as discussed under "Results and Discussion", out of the samples collected at the four different stages of harvesting in Series B, the first three samples were subjected to methods (a) and (g) only, but the last sample was subjected to the following four methods: (a), (c), (d) and (g). All the samples of Series A were subjected to method (a) only.

General characteristics. The fibres obtained were examined for colour and general condition and then subjected to measurement of reed length (3). Accordingly, lengths of individual reeds in the bundle were recorded.

Characteristics of ultimate fibres. The ultimate fibres were separated and their dimensions measured by the methods described by Maiti and Basu (13). In view of the importance of length (L) to diameter (B) ratio (viz L/B) in affecting strength and quality, (10, 11, 13-15, 17, 19, 20) the ratio was determinated for all the samples.

Strength characteristics. The strength of the fibres was determined by a pendulum type tensile testing machine, running on the 'constant rate of traverse' principle (1). In view of the preliminary investigations, 50 fibres per sample were tested. Further, in order to assess the effect of humidity on the strength, the strength was determined at three different levels of moisture. For the 40% r.h., a 47.71% solution of sulfuric acid (12) was employed; for 65% r.h., fibres were conditioned to standard room conditions and for 100% r.h., soaking in water was resorted to. Further, with a view to comparing suitability for practical purposes, strength of Ak twine was compared with that of jute. For this, twine of equal spyndle was prepared from the samples of Series A as well as from samples of jute and was subjected to strength test.

Results and Discussion. General characteristics of the Series A samples, are given below (Table-1).

Table 1

General characteristics of the Ak filaments from the (random) samples of Series A.

Sample No.	Colour	Reed length (cm)	Remarks
1.	fairly white	27	soft.
2.	fairly white	27	soft, fine.
3.	white	30	lustrous, soft, fine.
4.	dull	27	harsh.
5.	dull white	30	lustrous, soft, fine.
6.	dull	40	madium in feel and appearance.
7.	dull	27	harsh.
8.	fairly white	37	coarse.
9.	white	30	lustrous, soft,
10.	dull	27	soft.

The reed length varied between 2.7 to 40 cm. The colour also varied from white to dull and the feel from soft to harsh. These results hare to be expected in view of different origins of the samples.

General characteristics of the series B samples at various stages of maturity and employing different methods of retting are given in Table 2.

Table 2

General characteristics of Ak filaments from samples of (within plant) Series B.

Sample No.	Stage of maturity	Method of retting	Colour	Reed length (cm)	Remarks.
1.	Pre-flowering (March)	a	dull	27	fine, soft.
2.	—do—	g	white	30	lustrous, fine, soft.
3.	Early flowering (June)	a	dull	27	fine, soft.
4.	—do—	g	white	30	lustrous, fine, soft.
5.	Flowering (Sept)	a	dull	30	soft.
6.	—do—	g	white	33	lustrous.
7.	Late flowering (Dec.)	a	dull	30	coarse, harsh.
8.	—do—	c	white	37	coarse.
9.	—do—	d	white	37	coarse.
10.	—do—	g	white	43	coarse, harsh.

The reed length in this series varies between 27 to 43 cm and increases with maturity. Colour is dependent on the method of retting.

Experiments on both the series revealed the following general trends in the various procedures for extraction of fibres:

(*i*) Direct extraction whithout steaming, retting etc., yields the best fibre in terms of strength and colour but the production is the slowest, reed length is low and the produce is entangled.

(*ii*) Light beating of the stems in the beginning with a mallet as well as steaming assist in extraction.

(*iii*) Retting in water, in general, reduces fibre strength considerably. This results in fibre breakage and cosequent shorter reed length. A further disadvantage of the use of water is that the bark sticks more securely with the pith and when removed results in much shorter reed length. The prevalant bias against water retting (25) appears to stem largely from these factors, viz a lower wet strength (resulting in increased fibre breakage in the process of extraction) and a more secure sticking of the bark to the pith on wetting.

(*iv*) However, mild retting followed by partial drying for few hours facilitates extraction. The advantages of using alkaline medium are not clear. It rather darkens the colour.

(v) Stripping off the bark, followed by mild retting is considered to be the best approach as retting does not then lead to consequent breakage of strips and the reed length is high. Moreover, this approach would require smaller capital investment for construction of tanks for retting of strips only.

Table 3 gives strength characteristics for series A, at the three levels of r.h., 40%, 65% and 100%.

Table 3

Strength of Ak filaments at the three levels of r.h. for series A.

Sample No.	Tenacity g/tex		
	40% r.h.	65% r.h.	100% r.h.
1.	55.4	54.0	46.2
2.	57.7	53.0	45.3
3.	45.0	44.3	37.3
4.	60.4	52.8	45.7
5.	50.2	47.5	39.1
6.	61.7	56.4	47.4
7.	55.5	51.7	42.3
8.	47.4	44.6	38.2
9.	55.1	54.9	45.1
10.	57.8	44.4	44.4
Mean	54.62	50.36	43.10
S.D.	5.47	4.69	3.55
S.E.	1.73	1.48	1.13
95% C.L.	±3.39	±2.90	±2.21
99% C.L.	+4.43	+3.79	+2.89

The mean strength at 'standard' atmosphere is 50.36 ±2.90 g/tex. Under these conditions, the strength varies from 44.4 to 56.4 g/tex. These results are expected in view of the differences in origin of the samples.

The strength characteristics for series B at the three levels of r.h. are given in Table 4.

Table 4

Strength of Ak filaments and effect of moisture content in the case of (within plant) samples Series B.

Sample No.	Tenacity g/tex		
	40% r.h.	65% r.h.	100% r.h.
1.	46.8	42.4	37.1
2.	46.3	42.8	38.2
3.	47.1	43.9	38.4
4.	46.6	42.5	38.4
5.	47.0	43.3	39.6
6.	47.2	44.8	38.3
7.	48.7	46.7	40.3
8.	47.3	45.2	41.3
9.	49.1	45.5	41.5
10.	47.7	46.1	41.5
Mean	47.38	44.32	39.46
S.D.	2.70	1.45	1.61
S.E.	0.86	0.46	0.51
95% C.L.	$\pm$1.68	$\pm$0.91	$\pm$1.00
99% C.L.	+2.19	+1.18	+1.31

The mean strength for Series B at the 'standard' atmosphere is 44.32$\pm$0.91 g/tex and the values range from 42.4 to 46.1 from the pre-flowering to the late-flowering stage.

The following general trends for both the series were revealed for the strength characteristics.

(*i*) Strength decreases with moisture content. The mean specific strength was 54.62$\pm$3.39, 50.36$\pm$2.90 and 43.10$\pm$2.21 in the case of the series A for r.h. levels of 40%, 65% and 100%, respectively. The same trend was obvious in series B, where the corresponding values were: 47.38$\pm$1.68, 44.32$\pm$0.90 and 39.46$\pm$1.00, respectively. The decrease in tenancity from 40% r.h. to 65% r.h. was of the order of about 7% and that from 65% to 100% r.h. was about 13%. The overall decrease in tenancity from 40% r.h. to 100% r.h. was of the order of about 19%. Students 't' test was carried out to compare the differences in the tenacity at the various r.h. levels and the results are summarised in Table 5.

(*b*) Strength increases slightly with maturity. In Table 4, in the case of 65% r.h. the specific stress increased from about 42.5 g/tex to 46.0 g/tex from the pre-flowering to the late-flowering stage.

(*c*) The ultimate effect of the methods of retting employed on the strength of fibres is indiscernible.

(*d*) The range of values is obviously wider in the Series A, as the fibres had been collected from different sources. The values ranged between 44.3 to 56.4 g/tex at the 65% r.h.

Table 5

Comparison of strength of Ak fibres at various relative humidities: Students 't' test

	Tenacity values compared	't'value
	Series A	
1.	40% r.h. vs 65% r.h.	1.877
2.	65% r.h. vs 100% r.h.	3.862**
	Series B	
1.	40% r.h. vs 65% r.h.	3.159**
2.	65% r.h. vs 100% r.h.	7.089**

**Significant at the .01 level ('t' required: 2.878)

The values of specific stress at the 65% r.h. in Series A viz 44.3 to 56.4 g/tex (Table 3) compare with about 34 g/tex (on conversion of units) reported by A.H. Khan *et al* (8). It is, however, not known whether the authors evaluated *procera* or *gigantea* species. It is unfortunate that no other values for such an important characteristic as strength seem to be available for this fibre.

Table 6 summarises characteristics of the ultimate fibres in respect of the Series A.

Table 6

Characteristics of ultimate fibres of Ak for Series A.

Sample No.	Diameter μ	Length mm	L/B
1.	17.2	19.8	1151
2.	22.2	20.5	923
3.	25.8	22.3	864
4.	24.5	20.6	841
5.	19.9	18.0	905
6.	18.8	19.2	1021
7.	21.4	19.7	921
8.	26.3	21.7	825
9.	21.5	21.1	981
10.	23.4	20.4	872
Mean	22.10	20.33	930.4

The diameter of the ultimate fibres ranged between 17.2 and 26.73 μm with a mean of 22.10 μ. The values for length ranged between 18.0 and 22.3 mm with a mean of 20.33.

Table 7 gives characteristics of the ultimate fibres for Series B.

Table 7

Characteristics of ultimate fibres of Ak obtained from (within plant) samples of Series B.

Sample No.	Diameter μ	Length mm	L/B
1.	20.5	18.3	892
2.	19.4	18.4	948
3.	19.2	19.1	995
4.	21.0	19.6	833
5.	22.2	18.6	838
6.	20.6	19.9	966
7.	22.8	21.8	956
8.	21.4	20.7	967
9.	21.8	20.8	954
10.	22.7	20.9	921
Mean	21.16	19.71	927.0

The values for diameter were 19.2 to 22.8 with a mean of 21.16 μ, and for length were 18.3 to 21.8 with a mean of 19.71 mm. These values for diamteer compare with a value of 26.9 μ reported by A.H. Khan *et al* (7). It is, again unfortunate that no other values seem to be available for this important characteristic. The values for the length compare with a value of 30.3 mm reported by A.H. Khan *et al* (21).

The following general trends are obvious from the results for ultimate fibres:

(*i*) Diameter increases slightly with maturity. The increase is nominal up to the flowering stage, but on an overall basis from pre-flowering to late-flowering stage the trend is bovious. This is understandable since after attaining its height, the plant expands laterally, wherein secondary fibres are produced which are finer in diameter (22). This onset should suppress an increase in the mean value till the late stages of maturity.

(*ii*) Length also increases slightly with maturity. The above discussion also applies here.

(*iii*) L/B ratio virtually remains constant within Series B, averaging 927 (Table 7). In Series A, the ratio ranges between 825 to 1151 (Table 6). Comparing with corresponding specific stress values from Table 3, a positive correlation seems to exist: the higher the L/B value, the higher the strength. The coefficients of correlation between strength and L/B ratio have been given in Table 8. The coefficient in the case of Series A was +0.687 (significant at the 5% level) and in the case of Series B+0.509 (non-significant).

Table 8

Coefficients of correlation between tenacity at 65% r.h. and L/B ratio of Ak's ultimate fibres.

A:	Series	Co-efficient
A:	Random	+0.687*
B:	Within Plant	+0.509

* Significant at the 5% level.

It is unfortunate that no L/B ratios seem to have been reported by earlier workers for Ak. However, the ratio may be calculated on the basis of the only data reported by A.H. Khan *et al* (23, 24) for length and diameter of ultimate fibres. A ratio of 1148 thus obtained compares with the ranges of value discussed above.

The study of this anatomical character, viz L/B ratio, has recently made it possible to correlate fibre strength with measurable anatomical features. Thus Nandi (17) has very clearly demonstrated that widely differing fibres may be arranged in a descending order according to their L/B ratios as ramie (3000), flax (1700), cotton (316) and jute (14), corresponding to the descending values of their breaking loads. However, 'within' a particular fibre such a positive relationship could not be confirmed by Maiti and Basu (13). The results of present study give a positive correlation, significant for the random series, but non-significant for the within sample series. It would appear, therefore, that when the differences are large enough, in cases such as that at the between fibre level, the relationship gets fully expressed but for small differences of L/B ratio, other factors overshadow the relationship.

A comparison of strength of twine of equivalent spyndle made from Ak and jute (Table 9) reveals that Ak not only compares favourably with jute but is slightly stronger, indicating the suitability of the fibre for the range of end-uses dependent largely on such levels of strength. The strength trend is in general agreement with other studies, claiming a generally high vlue for the strength of Ak fibres, although early assertions have mostly been made qualitatively (5).

Table 9

Comparison of strength of equivalent twine samples of Ak and Jute (Lbs)

Sample No.	Ak	Jute
1.	17.8	17.1
2.	17.7	17.4
3.	17.9	17.1
4.	17.8	16.5
5.	17.9	17.7
6.	18.5	17.1
7.	18.1	16.5
8.	17.6	17.4
9.	18.0	16.2
10.	17.8	16.8
Mean	17.81	16.98

Conclusions

1. Stripping off the bast, retting of strips in water for 24-48 hrs, followed by drying for a few hrs and then extracting the fibres is considered to be the best general procedure for obtaining the fibre. Retting for longer intervals (especially of the whole stem) and extraction in the wet stage lead to weakening, fibre breakage etc. Among other factors, light beating of the stems with a mallet in the beginning and steaming assist positively.

2. The tenacity of various samples of Ak fibres obtanined from the northern part of Pakistan ranges between 44 g/tex to 65 g/tex.

3. The tenacity is not affected appreciably by the methods of retting investigated, some of which, however, affect colour of the fibre.

4. The tenacity increases slightly with maturity e.g., from a value of 42.5 g/tex at the pre-flowering stage to 46.0 g/tax at the late flowering stage.

5. The tenacity is significantly affected by relative humidity e.g.,the same fibres exhibited a tenacity of 47, 44 and 39 g/tax at the r.h. of 40%, 65% and 100%, respectively, showing a low wet strength. The suitability of the fibres for fishing nets etc. seems to depend on an initial high strength, which even on reduction in water is sufficient for the purpose.

6. The diameter of the ultimate fibres ranges between 17 to 26 μ, while the length ranges between 18 to 22 mm.

7. The ratio of length to diameter viz L/B ranges between 825 to 1150. This ratio appears to be related to tenacity positively: the higher the ratio, the higher the tenacity.

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