Pakistan J. Sci. Ind. Res., Vol. 23, No. 5 October 1980

# CHARACTERISTICS OF KENAF *(HIBISCUS CANNABINUS)* FIBRES

## Part I. Physical Characteristics

S.M.A. Shah, M.T. Younis and Ghulam Nabi

*PCSIR Laboratories,Peshawar*

(Received May 30, 1979; revised April 14, 1980)

Samples of kenaf, varieties vulgaris and viridix, collected at four different stages of maturity, viz pre-flowering, flowering, small pod and seed maturity, were subjected to a number of methods of retting. Fibres were investigated for fineness and length of ultimates and for tenacity at three different levels of R.H. viz. 40, 65 and 100%. Various relationships and trends were examined.

### INTRODUCTION

Kenaf *(Hibiscus cannabinus)* is long known as one of the important bast fibres, finding use in the manufacture of sacking, cordage, ropes, fishing nets etc., in addition to its use in the production of paper [1]. Recently, increased interest in the fibre is being shown [2–8] in view of several advantages for specific purposes. These include, e.g. for the purpose of production of paper: (i) possibility of using the whole plant, together with the woody core [2–4] and (ii) production of the plant on an annual basis (in contradistinction to wood forests), thus streamlining production and demand. In fact, the crop can be harvested within about 4 months and the dry matter yield is high. Likewise, for the purposes of textile and cordage, the conditions for growth of kenaf being less stringent than those for jute [9–11], it can be grown under wide-ranging conditions in comparison to the latter. This promises cultivation of a fibre closely resembling jute in areas deficient in jute.

As cited by Crane and Acuna [12], Howard and Howard recognised five different varieties of kenaf comprising eight agricultural types as early as in 1911. It appears, however, that most of the subsequent studies on physical and chemical characteristics of the fibre have, generally, not taken into account this fact of distinction among these varieties. Baque [13] studied differences in the five varieties largely from the viewpoint of growth, and yield; the study excluded the differences in the anatomical and chemical characteristics of the fibres. Studies have also revealed rather large differences in characteristics arising out of differences in location and climate [3–7]. In fact, the data available on the various characteristics of kenaf differs widely in values. Thus, for instance, mean values for the length of the ultimate fibres of kenaf have been reported to range from about 2.4 [14] to 3.3 mm [15]. It is obvious that a large part of these differences is attributable to such factors as variety, location and climate, in addition to differences in the techniques of anlaysis. Apart from these variations, the characteristics are alse dependent upon the stage of maturity and only a few studies (e.g. Clark *et al.* [7,8]) seem to have been carried out in the case of kenaf on these influences. In view of these facts, more studies on appreciation of physical and chemical characteristics of fibres from different areas and climates are warranted, especially when utilization of crops indigenous to various growing regions is under consideration.

The objectives of the present study were: (i) To compare and contrast characteristics of the fibres from the varieties viridix and vulgaris indigenous to Paksitan. (ii) To analyse effects of stages of maturity on the fibre characteristics. (ii) To analyse effects of different methods of extraction of fibres on the characteristics of fibres with a view to arriving at the optimum method. (iv) To analyse effects of level of moisture content on the strength of fibres, influencing the use of fibres for fishing and marine purposes.

### MATERIALS AND METHODS

*Samples.* Two varieties of kenaf viz vulgaris and viridix are generally grown in Pakistan, especially in the northern half of the country. Both these varieties were grown at the experimental farm of these Laboratories, adopting the practices common in the area. Accordingly, seed was broadcast at the rate of about 20 lb/acre on 20th May, 1974. In view of the soil conditions only a low dose of urea fertilizer at the rate of 30 lb/acre was served after 3 weeks of cultivation. Cultivation was repeated in 1975.

Samples were collected at the following four different stages of maturity: (1) Preflowering (after about 12 weeks of cultivation). (2) Flowering (after about 14 weeks of cultivation). (3) Small pod (after about 16 weeks of cultivation). (4) Seed maturity (after about 19 weeks of cultivation).

*Extraction of Fibres.* The samples obtained at the preflowering stage were subjected in a preliminary investigation to several different methods of retting as follows: (a) Green ribbons peeled off and retted in slow-flowing canal water. (b) Plants left to dry in the field, ribbons peeled off and retted in slow flowing canal water. (c) Green ribbons peeled off and retted in a closed tank. (d) Whole plants left to dry in the field and retted in closed tank. (e) Dry plants retted in a closed tank incorporating 1% urea. (f) Dry plants retted in a closed tank incorporating 1% NaOH.

Subsequently, methods (b) and (e) were selected for the purposes of samples obtained at the later stages.

*General Characteristics.* The fibres obtained were examined for general condition and colour and subjected to measurement of reed length [16]. Accordingly, lenghts of individual reeds in the representative bundles were recorded.

In the subsequent experiments fibre samples from the middle portions of the reeds were employed.

*Strength Characteristics.* The strength of technical fibres was recorded by a pendulum type tensile testing machine running on the 'constant rate of traverse' principle [17], employing a gauge length of 10 cm. Further, in order to assess the effect of moisture level on the strength, fibres were tested at three different levels of humidity. For the 40% RH, a 47.71% solution of sulfuric acid [18] was employed; for 65% RH, fibres were conditioned to standard room conditions, and for 100% R.H. soaking in water was resorted to.

*Characteristics of Ultimate Fibres.* Ultimate fibres were separated and their dimensions measured essentially by Maiti and Basu's method [19]. The diameter was, however, recorded at a magnification of 500x. In view of the importance of the length (L) to diameter (B) ratio, (viz L/B), in affecting strength and quality [19, 22–25], the ratio was determined for all the samples.

## RESULTS AND DISCUSSION

*General Characteristics.* General characteristics of the varieties vulgaris and viridix, at various stages of maturity and employing different methods of retting, have been given in Table 1.

The reed length varies between 2–3 m in the case of vulgaris, increasing with maturity and slightly affected by method of retting/extraction. Likewise, the variation in reed length in the variety viridix was also between 2–3 m, although the reeds were slightly longer in this case. The colour in both the cases seemed largely dependent on the method of retting. The terms light, medium and heavy have been used on a relative basis within the series.

These experiments on retting revealed the following trends: (i) Slow flowing canal water facilitates retting in comparison to closed tank. However, the former results in somewhat darker shades of the fibres. (ii) Green plants or ribbons take longer intervals for completion of retting than do the dry ones. (iii) Stripping off the bark, especially after drying the stock, and subjecting it to retting in a closed tank is considered to be a more economical method than that of immersing the entire stock. The approach would require smaller expenditure on transporting the ribbons to the tanks and smaller capital investment for construction of tanks for retting of the strips only. However, a slight disadvantage is that stripping results frequently in tapering

Table 1. General characteristics of kenaf.

| Sample No. | Stage of maturity | Method of retting | Colour | | Reed length (m) | |
|---|---|---|---|---|---|---|
| | | | Vulgaris | Viridix | Vulgaris | Viridix |
| 1 | Preflowering | a | Medium | Medium | 1.97 | 2.13 |
| 2 | " | b | Light | Light | 2.02 | 2.15 |
| 3 | " | c | Light | Light | 1.94 | 2.22 |
| 4 | " | d | Light | Light | 2.16 | 2.33 |
| 5 | " | e | Medium | Medium | 2.15 | 2.44 |
| 6 | " | f | Heavy | Heavy | 2.09 | 2.29 |
| 7 | Flowering | b | Medium | Medium | 2.34 | 2.51 |
| 8 | " | e | Light | Light | 2.53 | 2.43 |
| 9 | Small pod | b | Medium | Medium | 2.81 | 3.01 |
| 10 | " | e | Light | Light | 2.92 | 2.94 |
| 11 | Seed maturity | b | Medium, dull | Medium | 3.18 | 3.23 |
| 12 | " | e | Light | Light | 2.99 | 3.06 |

Table 2. Strength characteristics of kenaf tenacity (g/tex).

| Sample No. | Vulgaris 40% RH | Vulgaris 65% RH | Vulgaris 100% RH | Viridix 40% RH | Viridix 65% RH | Viridix 10% RH |
|---|---|---|---|---|---|---|
| 1 | 28.4 | 26.6 | 23.5 | 27.5 | 24.3 | 22.2 |
| 2 | 28.7 | 26.4 | 23.8 | 27.1 | 24.2 | 22.7 |
| 3 | 29.3 | 26.3 | 24.9 | 27.2 | 24.2 | 22.7 |
| 4 | 30.2 | 27.2 | 25.9 | 27.8 | 24.9 | 23.4 |
| 5 | 29.8 | 26.7 | 23.8 | 27.3 | 24.4 | 22.9 |
| 6 | 29.8 | 26.9 | 23.6 | 27.5 | 24.6 | 23.3 |
| 7 | 32.4 | 30.4 | 27.2 | 29.4 | 26.5 | 24.4 |
| 8 | 31.1 | 29.5 | 26.7 | 29.6 | 27.2 | 24.6 |
| 9 | 34.6 | 33.3 | 31.3 | 33.3 | 31.9 | 28.6 |
| 10 | 33.3 | 32.6 | 31.5 | 32.7 | 31.9 | 28.1 |
| 11 | 30.7 | 30.2 | 29.5 | 29.5 | 28.8 | 26.2 |
| 12 | 30.5 | 30.8 | 29.6 | 29.5 | 29.7 | 26.2 |
| Mean | 30.7 | 28.9 | 26.8 | 29.0 | 26.9 | 24.6 |

off, yielding a lower reed length. (iv) Closed tank retting can be enhanced by addition of small amounts of alkali, though at the risk of some darkening of the colour, especially in the case of caustic alkali.

*Strength Characteristics.* Table 2 gives strength characteristics for both the varieties at the three levels of RH viz 40, 65 and 100%. The tenacity was 30.7, 28.9 and 26.8 g/tex for vulgaris and 29.0, 26.9 and 24.6 g/tex for viridix, respectively.

The following points may be noted:

The tenacity increases, in general, with maturity, but decreases slightly towards the seed maturity stage. Unfortunately, literature on strength characteristics of kenaf, especially at different stages for maturity and regain is scarce. It seems obvious, however, from the present results that strength is highly dependent upon maturity, and for the fibre purposes, harvesting may not be undertaken earlier than the flowering stage.

The changes in strength at different levels of moisture assume two trends: (i) Up to the stage of flowering the decrease in strength with increase in moisture content from 40 to 100% RH is about 20%. (ii) However, at the seed maturity stage, the decrease in strength from the 40 to 100% RH level is only about 10%.

The scarce literature on the subject reveals slight lowering in strength on wetting [20]. It becomes apparent now that the decrease in strength is dependent on the stage of maturity in accordance with the above trends.

The mean strength of the varity vulgaris is higher than that of the viridix variety. The mean tenacity at the standard conditions for the former was 28.9 g/tex, while that for viridix was 26.9 g/tex. Under these conditions, the strength varies between 26.3–33.3 g/tex for vulgaris and 24.2–31.9 g/tex for viridix.

As for the effect of method of retting on strength, as investigated in the case of preflowering samples, it appears that method d (viz dry plants retted in closed tank) results in better strength values than do the others. In general, alkaline medium and canal retting weaken the fibres, while closed tank retting and clean water favour a high strength. The ultimate effects of the methods of retting on the strength of fibres do not, however, appear to be appreciable.

The range of tenacity values viz 24–33 g/tex compares generally with a range of 19–28 g/tex given by Maiti and Dasgupta [25], although a direct comparison is not possible owing to differences in the stages of maturity, variety etc. and experimental procedures. Unfortunately, systematic studies on the strength of kenaf fibres with due regard to different variations in origin and conditions are scarce, making comparison difficult.

*Characteristics of Ultimate Fibres.* Table 3 summarises the characteristics of the ultimate fibres in respect of both the varieties.

The diameter of the ultimate vulgaris fibres ranged between 18.1–19.5 $\mu$ with a mean of 18.5 $\mu$, while the length ranged between 2.23–2.44 mm with a mean of 2.32 mm. For viridix, the diameter ranged between 18.8–19.9 $\mu$ with a mean of 19.5 $\mu$, while the length ranged between 2.42–2.58 mm with a mean of 2.49 mm.

These values for diameter compare with 13.6–20.4 $\mu$ reported by Clark *et al.* [7] and 21 $\mu$ reported by Vetillart [26]. The values for length compare with 1.77–3.75 mm given by Clark *et al.* [7] and 2.4 mm reproduced by Kirby [14].

The following general trends are obvious from these

Table 3. Characteristics of ultimate fibres.

| Sample No. | Vulgaris | | | Viridix | | |
|---|---|---|---|---|---|---|
| | Dia (μ) | Length (mm) | L/B | Dia (μ) | Length (mm) | L/B |
| 1 | 18.4 | 2.24 | 121.7 | 19.8 | 2.48 | 125.5 |
| 2 | 18.5 | 2.30 | 124.3 | 19.7 | 2.50 | 126.9 |
| 3 | 18.4 | 2.30 | 125.0 | 19.2 | 2.42 | 126.0 |
| 4 | 18.3 | 2.28 | 124.6 | 19.6 | 2.43 | 124.0 |
| 5 | 18.5 | 2.23 | 120.6 | 19.5 | 2.51 | 128.7 |
| 6 | 18.3 | 2.32 | 126.8 | 19.1 | 2.42 | 126.7 |
| 7 | 18.1 | 2.42 | 124.7 | 18.8 | 2.44 | 124.3 |
| 8 | 18.6 | 2.31 | 124.2 | 19.1 | 2.43 | 126.9 |
| 9 | 18.7 | 2.37 | 126.7 | 19.6 | 2.54 | 129.6 |
| 10 | 18.8 | 2.36 | 125.5 | 19.4 | 2.55 | 130.9 |
| 11 | 19.5 | 2.44 | 127.7 | 19.9 | 2.58 | 129.6 |
| 12 | 19.4 | 2.43 | 126.8 | 19.8 | 2.58 | 130.3 |
| Mean | 18.5 | 2.32 | 124.8 | 19.5 | 2.49 | 127.5 |

Table 4. Coefficients of correlation between L/B ratio and tenacity.

| Variety | Coefficient |
|---|---|
| Vulgaris | 0.504 |
| Viridix | 0.135* |

*Significant at the 1% risk level

results on ultimate fibres: (i) The diameter seems to increase slightly with maturity, as is specially evident in the case of vulgaris. The departure from a systematic increase at the intermediate stages is underatandable since after obtaining its height, the plant expands laterally, wherein secondary fibres are produced which are finer in diameter [21]. This onset should suppress an increase in the mean value till late stages of maturity. (ii) Length also increases slightly with maturity. The above discussion also applies here. (iii) The L/B ratio ranges between 120.6–127.7 in the case of variety vulgaris and 124–130.9 in the case of viridix. Comparing with corresponding tenacity values from Tables 3 and 4 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 ratios are positive but only that for viridix viz +0.736 is significient at 1% risk level, while for vulgaris it is 0.504.

These values for L/B compare with a range of 83–127 given by Maiti and Dasgupta [25]. Although Clark *et al.* [7,8] have not given these ratios, a range of 117–192 may be deduced from their data on the bast fibres of kenaf.

The study of this anatomical character, viz L/B ratio, has recently made it possible to correlate fibre strength with measurable anatomical features [19, 22–25]. Thus Nandi [25] 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 (140), corresponding to descending order of their breaking loads. The results of the present study support these findings, in general.

## Conclusion

(1) Factors facilitating extraction of fibres include slow flowing water for retting, drying of the stock prior to retting, peeling off the dry bark and employment of small amounts of alkali in the medium. On an overall basis, stripping of the bark, especially after drying the stock, and then subjecting the same to retting in a closed tank is considered to be an effective and economical approach. This would require smaller expenditure in transporting the ribbons to the tanks and smaller capital investment for construction of tanks for retting of the strips only.

(2) The mean strength of the variety vulgaris (about 28.9 g/tex at the standard conditions) is higher than that of viridix (viz 26.9 g/tex).

(3) The strength increases, in general, with maturity, but decreases slightly towards the seed maturity stage.

(4) The strength decreases with moisture content. The decrease is more rapid up to the stage of flowering, but is nominal at the seed maturity stage. The fibres may, therefore, be employed with caution for fishing and marine purposes, especially where high wet strength is required.

(5) The ultimate fibres of variety vulgaris are smaller in size than those of viridix. However, as mentioned above,

the composite technical fibres of the former are stronger than those of the latter, indicating a negative relationship between the size of the ultimate fibre and strength of the composite fibre. The reasons for this may well lie in compositional and/or morphological factors and would require investigations by the workers in the related fields.

(6) The size of the ultimate fibre increases slightly, though irregularly, with maturity. The departure from a systemetic increase is understandable as, after obtaining its height, the plant expands laterally, wherein secondary fibres are produced which are finer in diameter [20]. This onset should suppress an increase in the mean value till late stages of maturity.

(7) The ratio of length of ultimate fibres (L) to their breadth (B), viz L/B, appears to have a positive relationship with the strength of the fibres in general agreement with certain recent studies [19, 22–25].

*Acknowledgements.* The authors are indebted to Dr. S.M.A. Kazmi for identification of the varieties and are thankful to Messers. Mohd. Raziq and Javed Khan for some of the routine measurements.

## REFERENCES


1. *Wealth of India* ( CSIR, Government of India Press, New Delhi, 1959), Vol. V, pp. 77.
2. H.J. Nieschlag, G.H. Nelson, I.A. Wolff and R.E. Perdue Jr., TAPPI, **43**, 193(1960).
3. H.J. Nieschlag, G.H. Nelson and I.A. Wolff, *ibid,* 44 516 (1961).
4. T.F. Clark, G.H. Nelson, H.J. Nieschlag and I.A. Wolff, *ibid,* 45, 980 (1962).
5. T.F. Clark and I.A. Wolff, *ibid,* **45**, 786 (1962).
6. G.A. White, *ibid,* **52**, 656 (1969).
7. T.F. Clark, S.C. Uhr and I.A. Wolff, *ibid,* **50**, 52A (1967).
8. T.F. Clark and I.A. Wolff, *ibid,* **52**, 2112 (1969).
9. Ref. 1, p. 78.
10. H.R. Maursberger, *Mathews Textile Fibres* (Wiley, New York, 1954), sixth edition, p. 328.
11. H. Kirby, *Vegetable Fibres* (Leonard Hill, London/New York, 1963), p. 104.
12. J.B. Crane and J.B. Acuna, Botan. Gaz., **106**, 344 (1945).
13. D.G. Baque, Phil. Agri., **37**, 130 (1953).
14. Anonymous quoted after ref. 11, p. 128.
15. O.O. Roberts, J. Text. Inst., **32**, 530 (1941) quoted after M. Harris, *Handbook of Textile Fibres* (Harris Research Laboratories, Washington, 1954), first edition, p. 119.
16. H. Chatterjee, J. Sci. Ind. Res., **18C**, 206 (1959).
17. ASTM Committee on Textile Materials, ASTM Standards on Textile Materials (American Society for Testing Materials, Pa, 1961), 32nd ed., Designation D.C. 76–53.
18. A.H. Lange, *Handbood of Chemistry,* (McGraw Hill, New York, 1961), tenth edition, p. 1423.
19. R.K. Maiti and N.C. Basu, Ind. J. Agri. Res., **38**, 724 (1968).
20. Ref. 10, p. 331.
21. Ref. 11, p. 4.
22. R.K. Maiti, Textile Digest, **30**, 69 (1970).
23. N.C. Rao and S.B. Salia, Indian Agri, **5**, 108 (1961).
24. H.K. Nandi quoted after ref. 19.
25. R.K. Maiti and A. Dasgupta, Textile Res. J. **42**, 648 (1972).
26. Vetillart, quoted after ref. 10, p. 330.