NOTE

Characterization of Cellulosic Fibers

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INTRODUCTION

Some plant fibers, particularly bast fibers, have not been characterized to evaluate their potentials as industrial raw materials. Natural fibers from plant sources are of particular interest because they feature a wide range of physicochemical properties, some of which are dependent on the nature of the plants and on the parts from which the fibers are derived.[1]

Several fiber plants exist in the tropics, which are less well known than the conventional ones, such as hemp and jute, but which may have comparable properties to the latter to justify their industrial applications as alternative sources of fibers.

This note is on the studies of bast fibers from seven plants, namely, *Hibiscus sabdariffa* (roselle), *Hibiscus cannabinus* (kenaf), *Urena lobata* (caesarweed), *Corchorus fascularis* and *Adansonia digitata* (boabab), and *Urtica dioica.* Their physicochemical properties are reported.

EXPERIMENTAL

The fibers were delignified, and the tensile properties were determined at 30°C using Instron model 220D testing machine at a crosshead speed of 3 mm min^{-1} and a gauge length of 25 mm. The sample length was 50 mm, and the average of five determinations was taken for each sample. The crude fiber, ash contents, and fiber densities were determined by standard methods.[2–4]

RESULTS AND DISCUSSION

The stress–strain curves for the fibers are represented in Figures 1 and 2. They all show characteristic crimp since the fibers were not subjected to pretension at the start of the tensile test. The extrapolated points give values for the crimp and correspond to the zero position for hypothetical straight fibers.[1] The tensile properties for the fibers were derived from the curves and are represented in Table I. The crimp values range from 0.9–2.4%, with the highest value being for *C. fascularis.*

The initial moduli for the fibers are in the range of 1.4–5.25 $Ntex^{-1}$, with *U. lobata* having the highest value. The order of moduli for the fibers is *U. lobata* > *C. fascularis* > *U. dioica* > *H. cannabinus* > *H. sabdariffa* > *H. esculentus* > *A. digitata.* The moduli are low relative to the values for flax (18.0 $Ntex^{-1}$), jute (17.2 $Ntex^{-1}$), hemp (21.7 $Ntex^{-1}$), and ramie (14.6 $Ntex^{-1}$).[1] The high moduli for these fibers are associated with a high orientation of the cellulose molecules and the bast bundles lying along the full length of the stem.[1,5] The specific work of rupture for the fibers, after correction for crimp, ranges between 1.29 and 4.43 $mNtex^{-1}$ and is in the order of *H. cannabinus* > *U. dioica* > *H. sabdariffa* > *U. lobata* > *H. esculentus* > *C. fascularis* > *A. digitata.* These values are, in general, comparable to the average ones reported for flax (8.0 $mNtex^{-1}$), Jute (2.7 $mNtex^{-1}$), and hemp (5.3 $mNtex^{-1}$).[1] In the case of jute, however, the specific work of rupture is significantly lower than the values for *H. cannabinus* (4.43 $mNtex^{-1}$), *U. dioica* (3.38 $mNtex^{-1}$), and *H. sabdariffa* (3.34 $mNtex^{-1}$) by up to a factor of 3. Thus, for certain applications, these fibers may be superior to jute fibers.

The values for tenacity for the fibers are not higher than 0.19 $Ntex^{-1}$ and are in the range of 0.05–0.19 $Ntex^{-1}$, with the lowest and the highest being values for *A. digitata* and *U. lobata,* respectively. The tenacity for flax (0.54 $Ntex^{-1}$), jute (0.31 $Ntex^{-1}$), hemp (0.47 $Ntex^{-1}$), and ramie (0.59 $Ntex^{-1}$)[1] are significantly higher by a factor of up to 3 than the value for *U. lobata.*

The breaking extension for the fibers after the correction for crimp is in the range of 3.7–5.6%, with the

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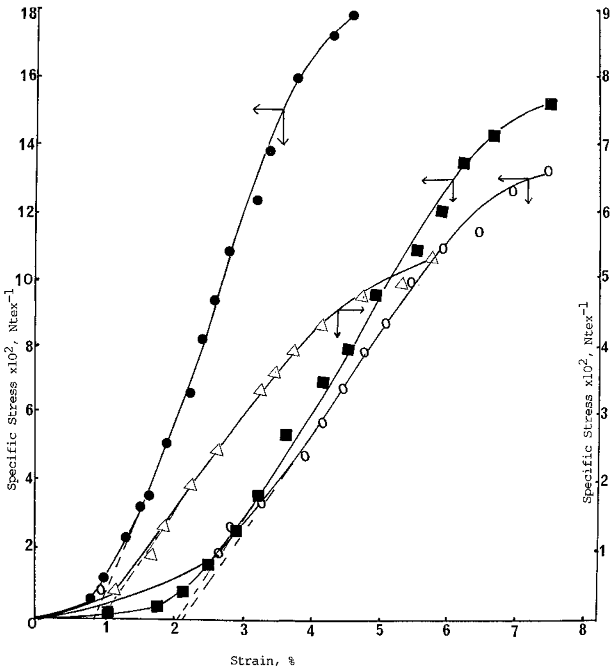

Figure 1 Stress–strain curves of fibers: (○) *Hibiscus sabdariffa;* (■) *Hibiscus cannabinus;* (●) *Urena lobata;* (△) *Adansonia digitata.*

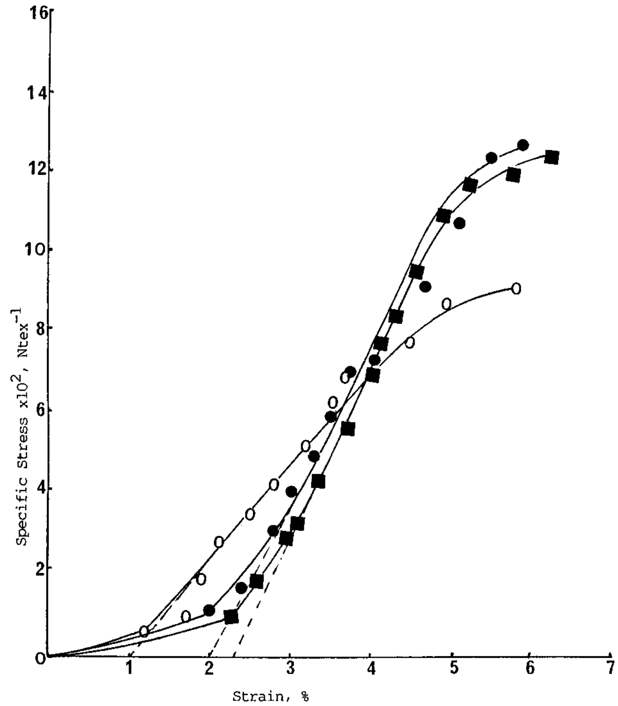

Figure 2 Stress–strain curves of fibers: (○) *Hibiscus esculentus;* (■) *Corchorus fascularis;* (●) *Urtica dioica.*

lowest and the highest being values for *U. lobata* and *H. cannabinus,* respectively.

The fibers show varying crease recovery properties, as shown in Table I, ranging from 18.4–29.9%. The values for *U. lobata* (29.9%), *U. dioica* (27.8%), and *H. sabdariffa* (24.9%) indicate higher levels of crease recovery compared with the other fibers.

The plots of moisture retention versus time at 60°C for the fibers are represented in Figures 3 and 4. The initial rates of moisture loss derived from the plots are shown in Table II. The rate of moisture loss varies between 5.66×10^{-3} and 6.94×10^{-3} g min^{-1}. *U. lobata* shows a superior moisture retention property by its lowest value of 5.66×10^{-3} g min^{-1} for the initial rate of moisture loss. However, at equilibrium, *H. sabdariffa* and *U. lobata* retained the highest level of moisture at 47.7%. The removal of water from masses of fabrics has practical application in the drying of tex-

Table I Tensile Properties of Fibers

Fibers	Initial Modulus (Ntex^{-1})	Specific Work of Rupture (mNtex^{-1})	Tenacity (Ntex^{-1})	Breaking Extension (Corrected for Crimp) (%)	Crimp (%)	Work Factor	Crease Recovery (%)
Urtica dioica	3.73	3.38	0.13	3.9	2.0	0.5	27.8
Hibiscus sabdariffa	2.92	3.34	0.13	5.4	2.1	0.5	24.9
Hibiscus cannabinus	3.38	4.43	0.15	5.6	2.1	0.5	20.4
Urena lobata	5.25	2.88	0.19	3.7	0.9	0.5	29.9
Corchorus fascularis	4.25	2.39	0.13	3.9	2.4	0.5	18.4
Hibiscus esculentus	2.31	2.49	0.09	4.8	1.0	0.5	—
Adansonia digitata	1.40	1.29	0.05	4.8	1.0	0.5	20.7

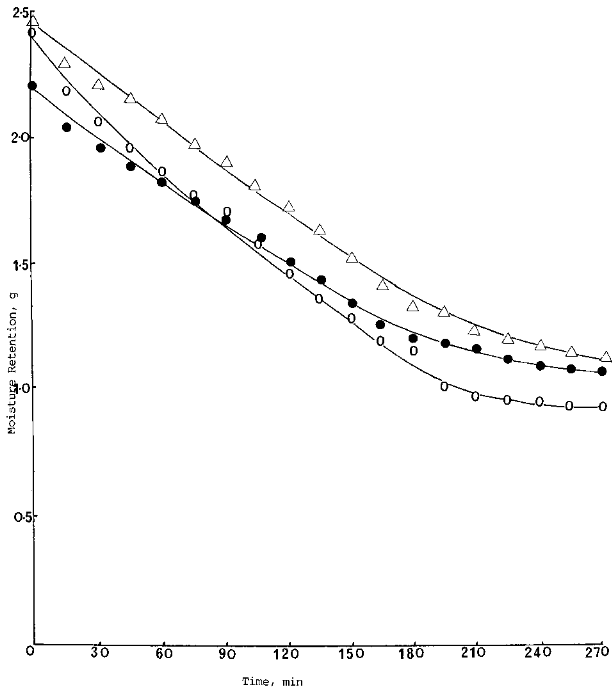

Figure 3 Moisture retention curves of fibers at 60°C: (△) *Corchorus fascularis;* (○) *Hibiscus cannabinus;* (●) *Hibiscus sabdariffa.*

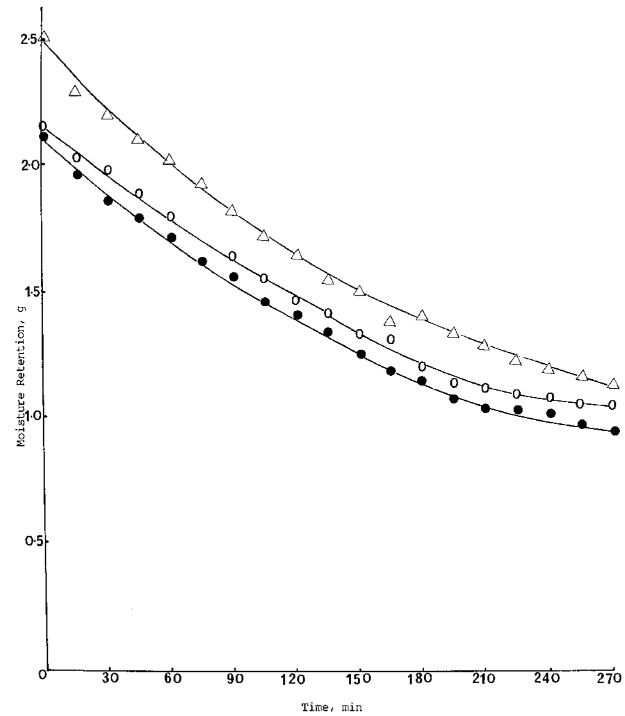

Figure 4 Moisture retention curves of fibers at 60°C: (△) *Adansonia digitata;* (○) *Urena lobata;* (●) *Urtica dioica.*

tiles. Water is held by surface tension in capillary spaces between fibers. The exact form of the spaces is dependent on the way in which the fibers are packed together.[1] Preston et al.[6] have shown that less water was held by randomly oriented viscose rayon fibers than by the parallel ones. Thus, the varying levels of moisture retention, as shown for the fibers in Table II, must reflect, in principle, the different morphological features of the fibers.

The composition and density of the fibers are shown in Table III. The range of densities is 0.84–1.45 g cm^{-3}. As can be seen, all the fibers have higher densities than water, with the exception of *H. esculentus,* with a lower value of 0.84 g cm^{-3}. Fiber density is believed to be closely related to the mechanical properties, moisture absorption, homogeneity, and degree of order of the fiber.[7] For *H. esculentus,* it is evident that the density is low when compared with values normally found for cellulosic fibers,[7,8] that is, 1.45–1.65 g cm^{-3}, and suggests the presence of internal void spaces in the fibers.[1]

The crude fiber contents are close for all the fibers ranging from 53.23–65.42% and are comparable to values for other fibers,[9–11] namely, sisal (62%), flax (71.2%), hemp (74.3%), and kapok (43.2%). The moisture content is not higher than 6.72% in the fibers, but the ash content is significant, with values of up to 6.48% in *H. esculentus.*

CONCLUSION

The tensile moduli of the fibers, in the range of 1.40–5.25 $Ntex^{-1}$, are lower than the values for conventional cellulosic fibers, namely, jute, hemp, flax, and ramie. However, the specific work of rupture for *H. cannabinus* (4.43 $mNtex^{-1}$), *U. dioica* (3.38 $mNtex^{-1}$), and *H. sabdariffa* (3.34 $mNtex^{-1}$) are higher than the value for jute by a factor of up to 3. The fibers show significant crease recovery capabilities with the highest value of 29.9% for *U. lobata.*

Table II Initial Rate of Moisture Loss by Fibers at 60°C

Fiber[a]	Rate × 10^3 (g min^{-1})	Equilibrium Moisture Retention (%)
U. dioica	6.94	42.8
H. sabdariffa	6.04	47.7
H. cannabinus	6.91	37.5
U. lobata	5.66	47.7
C. fascularis	6.66	44.8
A. digitata	6.11	44.0

[a] Weight of Fiber: 1.0 g.

Table III Composition and Density of Fibers

Fibers	Density (g cm^{-3})	Crude Fiber (%)	Ash (%)	Moisture (%)
Urtica dioica	1.45	65.42	4.16	6.07
Hibiscus sabdariffa	1.28	63.81	3.25	—
Hibiscus cannabinus	1.36	53.37	2.42	6.62
Urena lobata	1.40	63.97	1.72	6.72
Corchorus	1.16	53.32	2.98	5.48
Hibiscus esculentus	0.84	59.94	6.48	6.48
Adansonia digitata	1.25	62.34	4.45	6.00

The moisture retention of the fibers at 60°C yield equilibrium values of up to 47.7% for *H. sabdariffa* and *U. lobata.*

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