SUITABILITY OF SOME WOODY AND NON-WOODY RAW-MATERIALS FOR PULP AND PAPER AS BASED ON FIBER DIMENSION

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ABSTRACT

Pakistan is deficient in pulp and paper. This is mainly because of shortage of raw material for this industry in the country. To broaden the raw material base for paper manufacture, studies were under taken to investigate the suitability of some of the home grown materials like woods, grasses and shrubs, for this use, on the basis of their fiber dimensions. Among all the species investigated softwoods are the best material for pulp and paper, followed by bamboos and other grasses. Most of the hardwoods and shrubby materials yield short fiber. To produce a strong paper from hardwoods and shrubby materials use of a pulp furnish of softwoods and/or bamboos is recommended. In addition to fiber dimensions, economic availability is the main governing factor in the use of a raw material for pulp.

INTRODUCTION

There is a shortage of pulp and paper in Pakistan. The local production of paper and paper products is not enough to meet the domestic needs. Therefore, a foreign exchange of Rs.3,034 million (Anonymous, 1994) is annually spent on the import of this commodity. The main reason for low local production is the shortage of raw-material for paper industry. The known sources of pulp are in short supply and the potential sources are yet to be explored. There are two important considerations for the suitability of a raw-material for pulp and paper manufacture. One is the chemistry and economy of pulping and the other is the fiber dimensions of the raw-material which, largely, influence the strength properties of paper.

Casey (1979) and Dinwoodie (1965), reported a correlation between fiber dimension and paper properties. Tear strength of paper directly depend upon fiber length. The longer the fiber the higher is the tear strength. Relative fiber length is the fiber length/diameter ratio and is an expression of slenderness of the fibers or flexibility. High relative fiber length and fiber flexibility is desirable for better felting power and high bond strength of paper. Runkel ratio is a ratio between double of fiber wall thickness and fiber lumen diameter. The fibers with higher Runkel ratio have relatively thick walls, are stiffer, less flexible and therefore, form bulkier paper with low bonded area. A Runkel ratio of 1 or lesser is desirable to form paper with high bond strength. Softwoods mostly have an average fiber length of 3-4 mm and are known as "long fiber" (Clark, 1981). Fiber length in hardwoods is largely between 1-1.5 mm and produce "short fiber". Grasses, especially bamboo have fiber length between 2-3 mm and therefore, can be termed as "medium long fiber".

There are many potential sources of fibers in Pakistan, comprising of different types of hardwoods, softwoods, grasses and other shrubby materials. However, their fiber dimensions need to be investigated to anticipate the quality of paper manufactured from them. With this objective in view, studies were carried out at the Forest Products Research Division, Pakistan Forest Institute, Peshawar on fiber characteristics of different fibrous raw-materials, such as fiber length, relative fiber length and Runkel ratio, for their relative suitability for pulp and paper, as based on these parameters.

MATERIAL AND METHODS

- Material:

The samples of various wood species studied, were obtained from permanent collection of authentic wood specimens procured from different parts of Pakistan. The samples of Khip (*Leptadenia pyrotechnica*) and Mazri (*Nannorrhops ritchiana*) were obtained from Gilgit, Northern Areas and Hangu area of Kohat Forest Division, respectively. Samples of bamboo species were obtained from the Silvicultural Research Garden, Pakistan Forest Institute, Peshawar and of other grasses and shrubs, both wild and cultivated, were collected from the areas in and around Peshawar.

- Methods:

Maceration

For measurement of fiber length, match-stick sized pieces of woods, the middle part of the shrubby materials, Mazri leaf and petiole, grasses (leaves+culms) and bamboos were taken and boiled in water till these were fully waterlogged. Maceration of each material was carried out by Schultze's method (Gatenby and Beams, 1950) in a test tube. For bamboo species, match-stick sized pieces from outer, middle and inner portion of the wall of the culm were taken and macerated separately. Macerated material for each species was thoroughly washed in water and fibers separated with the help of a hand centrifuge. Fibers were stained by teasing them in a drop of weak solution of methylene blue on a slide. Temporary slides of fibers were made for measurement of fiber length.

Sectioning

20 micron thick, free hand cross sections of water soaked woods, middle portion of leaves and culms of grasses, bamboos and leaf and petiole of Mazri were cut on a sliding microtome. This was done by holding a convenient sized piece of leaf and culm in the slot made in a soft and water soaked wooden block of about 1.5x1.5 cm cross section. The recesses between the material and slot were filled with 10% celloidin ether-alcohol solution and hardened in chloroform. This wooden block, holding the piece of material, was attached to the microtome, properly orientated, and sectioned. For sectioning of woods, petiole of Mazri and culms of bamboo species, convenient sized pieces of these materials were directly attached to the microtome. During sectioning of grasses (leaves+culms), culms of bamboo and leaf and petiole of Mazri, after each sectioning stroke the cut faces were coated with a thin layer of 10% celloidin ether-alcohol solution. This was done to ease sectioning. Celloidin from the sections was later on mechanically removed after immersion under water till the film of celloidin started loosening from the sections.

Staining

Depending upon the material the cross sections were either stained in safranin (woods) or given a double staining (Johansen, 1940)) with safranin and fast green (non-woody materials). Stained sections were rinsed in water and then dehydrated after passing them through a series of alcohol-water mixtures of increasing concentration upto 100% of alcohol. The rate of destaining in 100% (absolute) alcohol was carefully watched and at the required point the sections were quickly cleared in clove oil. Temporary slides of stained cross sections were made by mounting them in clove oil on a glass slide and covered with a cover glass.

Fiber Measurement

All measurements were taken under proper magnification of microscope with the help of an eye-piece micrometer. Fiber length, fiber diameter and lumen diameter were measured from the temporary slides of woods, leaves, petiole of Mazri, culms of grasses and bamboos. 50 measurements of fiber length and 25 measurements each for fiber diameter and lumen diameter were taken.

Analysis of Data

Average values of different fiber dimension were calculated. In case of bamboo species the fiber measurements from outer, middle and inner portion of the wall of the culm were averaged. From the average fibre dimensions the other fibre values like Relative Fiber Length (fiber length/fiber diameter) and Runkel Ratio (2x cell wall thickness/lumen diameter) were also calculated.

RESULTS AND DISCUSSION

b. Fiber Characteristics:

The results on fiber length and other fiber characteristics of grasses, bamboos, woods and shrubby materials are given in table 1. These results on the average fiber length, relative fiber length and Runkel ratio with respect to the nature of material are also discussed as under:

I. GRASSES:

i. Fiber Length

As shown in table 1, the average fiber length of grasses, both wild and cultivated, vary between 0.87 and 2.43 mm for Rice straw (*Oryza sativa*) and Sugar-cane (*Saccharum officinarum*), respectively Both these extremes are for cultivated grasses. Among all the 10 species of grasses studied, only one species has an average fiber length of less than 1, five have an average fiber length of more than 1 mm and four have an average fiber length of more than 2 mm. On the basis of fiber length sugar-cane bagasse is the best material for pulp and paper followed by Suriala (*Heteropogon contortus*), Nal (*Arundo donax*) and Wheat straw (*Triticum aestivum*) having an average fiber length of 2.29, 2.15 and 2.08 mm, respectively. For babbar grass the literature reported figure of fiber length is 2.02 mm (Bhat, et al, 1960), against this a fiber length of 1.23 mm, is measured in this study. This could be due to the difference in ecological conditions between the two localities. With some exceptions, the grasses generally are grouped as "medium long fiber" and are good for producing a paper of high tear strength.

ii. Relative Fiber Length

The relative fiber length of all the grass species vary between 80 for Kai (*Saccharum spontaneum*) and 258 for Jawar (*Sorghum vulgare*). Two of the grass species have a relative fiber length of less than 100, six have more than 100 and tow have more than 200. High relative fiber length of grasses, generally, is good for producing a pulp with high felting power and bond strength.

iii. Runkel Ratio

The Runkel ratio of grasses vary between 0.73 for wheat straw and 2.90 for rice straw. Two of the grass species studied have a Runkel ratio of less than 1, five have more than 1 and three have more than 2. Except for wheat straw and sugar-cane the Runkel ratio of grasses is generally high, which shows that the grass fibers are comparativ ely stiffer and less flexible to produce bulkier paper with low bond strength. However, this weakness is well compensated by higher fiber and relative fiber length in grasses.

Table 1 Fiber characteristics of different fibrous materials

Material		Av. Fiber Length (mm)	Relative Fiber Length	Runkel Ratio
I. <u>GRASSES</u>				
(a). Wild				
1. Nal	(*Arundo donax*)	2.15	197	2.1
2. Khawi	(*Cymbopogon jawarancusa*)	1.43	143	2.4
3. Babbar	(*Eulaliopsis binata*)	1.23	90	1.9
4. Suriala	(*Heteropogon contortus*)	2.29	201	1.5
5. Garam	(*Panicum antidotale*)	1.46	101	1.8
6. Kai	(*Saccharum spontaneum*)	1.32	80	1.6
(b). Cultivated:				
1. Rice	(*Oryza sativa*)	0.87	124	2.9
2. Sugar-cane	(*Saccharum officinarum*)	2.43	169	0.82
3. Jawar	(*Sorghum vulgare*)	1.86	258	1.4
4. Wheat	(*Triticum aestivum*)	2.08	118	0.73
(c). Bamboos				
1. Bans	(*Dendrocalamus hamiltoni*)	2.91	162	1.95
2. Bans	(*Dendrocalamus strictus*)	2.24	122	1.37
3. Kala bans	(*Bambusa tulda*)	2.41	149	2.18
II. <u>WOODS</u>				
(a). Hardwoods				
1. Paper mulberry	(*Broussonetia papyrifera*)	1.01	91	0.48
2. Eucalyptus	(*Eucalyptus camaldulensis*)	0.82	75	0.95
3. Eucalyptus	(*Eucalyptus tereticornis*)	0.73	63	1.80
4. Palachh	(*Populus ciliata*)	1.41	85	0.68
5. Bhan	(*Populus euphratica*)	1.54	94	0.85
6. Hybrid poplar	(*Populus euroamericana*)	1.33	81	0.47
7. Poplar	(*Populus nigra*)	1.07	67	0.60

(b). Softwoods			
1. Fir (*Abies pindrow*)	4.50	141	0.33
2. Deodar (*Cedrus deodara*)	4.34	140	0.35
3. Spruce (*Picea smithiana*)	3.60	129	0.17
4. Chir pine (*Pinus roxburghii*)	5.30	143	0.37
5. Blue pine (*Pinus wallichiana*)	4.42	138	0.10
III. SHRUBBY MATERIALS			
1. Sunflower (*Helianthus anus*)	0.92	75	0.41
2. Khip (*Leptadenia pyrotechnica*)	0.68	40	0.46
3. Mazri (*Nannorrhops ritchiana*)	2.12	213	0.83
4. Jantar (*Sesbania aegyptica*)	0.90	66	0.56

Reported fiber values are based on single sample therefore, variations due to sampling and locality are taken for granted.

BAMBOOS

i. Fiber Length

The average fiber length of various bamboo species is measured as 2.91, 2.41 and 2.24 mm for *Dendrocalamus hamiltoni*, *Bambusa tulda* and *D. strictus*, respectively. Except for softwoods, bamboos have the highest fiber length even among the other grasses investigated. Therefore, all the species of studied bamboos are very much suited for the manufacture of paper of good tear strength. The fibers of bamboos are categorized as "medium long" and therefore, also recommended as furnish to the hardwood pulps to improve felting and tear resistance.

ii. Relative Fiber Length

Relative fiber length of the three bamboo species is 162, 149 and 122 for *Dendrocalamus hamiltoni*, *Bambusa tulda* and *D. strictus*, respectively. *Dendrocalamus hamiltoni* has the highest relative fiber length of 162, while a minimum of 122 is for *Dendrocalamus strictus*. The relative fiber length of all the three bamboo species is well above 100 and therefore, all are well suited to produce a pulp of good felting power and a paper of high bond strength.

iii. Runkel Ratio

The Runkel ratio of bamboo species is 2.18, 1.95 and 1.37 for *Bambusa tulda*, *Dendrocalamus hamiltoni* and *D. strictus*, respectively. In all these cases the Runkel ratio is more than one. On the basis of Runkel ratio the fibers of bamboos are comparatively stiffer and less flexible. But this weakness of bamboo fibers is well compensated by their higher fiber and relative fiber length.

II. WOODS

a. Hardwoods:

i. Fiber length

The average fiber length of the investigated hardwood species vary from 0.73 mm for Eucalyptus (*Eucalyptus tereticornis*) to 1.54 mm for Bhan (*Populus euphratica*). All the poplar species have an average fiber length of more than 1 mm and both the *Eucalyptus* species have an average fiber length of less than 1 mm. All the hardwood species studied come under the category of "short fibers". Poplar species and paper mulberry can produce a reasonably strong paper even without the furnish of long fiber. But pulp from other hardwoods need some long fiber furnish to improve felting power and bond strength of the paper.

ii. Relative Fiber Length

Relative fiber length of all hardwood species is less than 100, varying from 63 for *Eucalyptus tereticornis* to 94 for bhan. This shows that the fibers of hardwoods are less slender than grasses and therefore, need some pulp furnish to improve felting power and strength of the paper.

iii. Runkel Ratio

Runkel ratio of investigated hardwood species vary between 0.47 for Hybrid poplar (*Populus euroamericana*) and 1.80 for *Eucalyptus tereticornis*. Except for *Eucalyptus tereticornis* the Runkel ratio of all the rest of studied hardwoods is less than one. Therefore, on this basis are suited to produce a paper of good bond strength.

b. Softwoods:

i. Fiber Length

The average fiber length of the investigated softwoods vary between 3.60 mm for Spruce (*Picea smithiana*) and 5.30 mm for Chir pine (*Pinus roxburghii*). Deodar (*Cedrus deodara*), Blue pine (*Pinus wallichiana*) and fir (*Abies pindrow*) have an average fiber length of 4.34, 4.42 and 4.50 mm, respectively. On the basis of fiber length all the local softwoods are categorized and "long fiber". High fiber length of softwoods make these very much suited for the production of paper of high tear strength. Pulp from softwoods being long fiber is also recommended as furnish to the other short fiber pulps, like that of hardwoods, to improve tear strength of the paper.

ii. Relative Fiber Length

Relative fiber length of all of the softwoods is more than 100, varying between 129 for spruce and 143 for chir pine. Blue pine, deodar and fir have an average relative fiber length of 138, 140 and 141, respectively. High relative fiber length shows that softwood fibers are very slender and are ideal for the production of pulp with high felting power and bond strength.

iii. Runkel Ratio

Runkel ratio of all the softwood species is very low varying between 0.10 for blue pine and 0.37 for chir pine. Spruce, fir and deodar have Runkel ratios of 0.17, 0.33 and 0.35, respectively. Low Runkel ratio of softwood fibers make these highly flexible suited to produce pulp of very high bond strength.

III.SHRUBBY MATERIALS:

i. Fiber Length

The average fiber length of shrubby materials vary between 0.68 mm for Khip (*Leptadenia pyrotechnica*) and 2.12 mm for Mazri (*Nannorrhops ritchiana*). Jantar (*Sesbania aegyptica*) and Sunflower (*Helianthus anus*) have an average fiber length of 0.90 and 0.92 mm, respectively. Except for mazri rest of the three species have an average fiber length of less than 1 and therefore, are categorized as "short fiber". On the basis of average fiber length mazri is grouped among the "medium long fiber" and therefore, is suited to produce a paper of good tear resistance. Pulp from rest of the three sources shall have to be mixed with some long fiber pulp for better strength qualities.

ii. Relative Fiber Length

The relative fiber length of the shrubby materials vary between 40 for khip and 213 for mazri. Jantar and sunflower stalk have a relative fiber length of 66 and 75, respectively. Except for mazri, rest of the three species have relative fiber length of less than 100. On the basis of relative fiber length the fiber of mazri are suited to produce a paper with good felting power and bond strength. Fibers from other three sources need a suitable furnish for improved felting power and bond strength.

iii. Runkel Ratio

The value of Runkel ratio for all the shrubby materials studied is less than 1. It varies between a minimum of 0.41 for sunflower to a maximum of 0.83 for mazri. Khip and jantar have Runkel ratio of 0.46 and 0.56, respectively. Low Runkel ratio of shrubby materials make their fibers flexible to produce a paper of good bond strength.

CONCLUSIONS

Among all the species investigated softwoods are the best material for pulp and paper because of their high fiber length, relative fiber length and very low Runkel ratio. It is a universal fact through out the world that softwoods produce long fiber pulp and are ideal for this use. Fibers of grasses, in most cases, especially bamboos stand next to softwood for their suitability for pulp and paper on the basis of their fiber dimensions. Hardwoods and shrubby materials except mazri, yield short fiber. To produce a strong paper from hardwoods and shrubby materials, other than Mazri, use of a pulp furnish of softwoods or bamboos is recommended. In addition to fiber morphology, economic availability is the governing factor in the use of a raw material as a source of pulp.

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