Studies On Paper Grade Pulp Form Certain Wild Plant Species

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ABSTRACT

The paper highlights the laboratory scale investigation on utilization of certain potential wild plant species viz. *Musa velutina, Clynogynae dichotoma* and *Cannabis sativa* for making paper grade pulp. The morphological properties and proximate chemical analysis of the plants were studied in the field as well as in the laboratory. *M. velutina* grows wild in the hilly areas while *C. dichotoma* grows in the low-lying areas in the forest. *C. sativa,* although a wild plant, is also cultivated in rural areas of Assam and other N E states. Under the climatic condition of N E region, *M. velutina* grows up to a height of 3.50 m while the height recorded for *C. sativa* and *C. dichotoma* were 1.35 and 2.80 m respectively. The stem diameter was recorded for *M. velutina, C. dichotoma* and *C. sativa* were 25, 3.0 and 3.20 cm respectively. The numbers of sheath in the stem of *M. velutina* were 10-12 while barks present in the stem of *C. dichotoma* and *C. sativa* were 20 and 22% respectively. The results of the proximate chemical analysis of the plant showed cellulose content 60.2% in *M. velutina* while 37.5 and 50.8% in *C. dichotoma and C. sativa,* so also, lignin content recorded 4.8 16.2% and pentosan from 8.7 -20.2%. The fibre yield in the outer sheath / bark was recorded 52.2%, 48.5% and 54.4% while pulp yield recorded 45%, 42% and 48.5% respectively for *M. velutina*, *C. dichotoma* and *C. sativa*. The Kappa number of the pulps were varied from 27-32. The physical strength properties of laboratory hand paper sheet were found satisfactory with the tensile index 58.65, 60.82 and 62.67 Nmg^{-1} for *M. velutina C. dichotoma and C. sativa* unbleached pulp. The burst index values varied from 4.7 – 5.8 $kPam^2g^{-1}$. The other physical strength properties of paper sheets viz. tear index, folding endurance, double fold etc. were also found satisfactory and lies within the acceptable range, comparable to other conventional cellulosic raw material. The physical strength properties of the paper sheets may further be enhanced by 20-30 % if the pulp fibres of outer sheaths / barks prepared separately and blended with the pulps obtained from remaining portion of the plants.

Introduction

Due to the rapid growth of population and industry, the forest areas of our country are gradually diminishing and at the same time the supply of plant raw materials from the forest to the industry is also decreasing at an alarming rate resulting in the shortage of plant raw materials for various forests and cellulosic based industries (1). The shortage of cellulosic raw materials are not only faced by the Indian paper industries but also throughout the world (2). Therefore, in recent years attention has been given on utilization of new pulp wood species and non-conventional short rotation plants (3, 4) to meet the demand of cellulosic raw materials in our country.

Assam and other NE states are very much rich in biodiversity. Due to varied topographic and climatic conditions, various types of flora with their own distinctive characteristics are grown naturally in the forests of this part of the country. Many of the plant species have medicinal and aromatic value, while some others bear good quality fibre. The agro climatic conditions of NE region of India are very much suitable to grow different types of plants, vegetables and agricultural crops. Apart from rice, wheat, sugarcane, jute etc. there are some other crops growing abundantly in this region. After harvesting the crops, the plants remain as waste in the field. Also, there are some weed species growing wild in the forest every year and decay in the forest without any use. As these plants are not being used so far for any commercial exploration, therefore an investigation was undertaken to study on pulp and paper making properties of these plants growing under the agroclimatic condition of Assam and the results obtained from the investigation are presented in this communication.

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Experimental

Materials:

Three plant species viz. *Musa velutina, Clynogynae dichotoma* and *Cannabis sativa* were selected for the present study because of easy availability good fibre quality and easy for processing. Matured plants of all the three species were collected from the different areas of Jorhat (26.47 ^{0} N L 94.12 ^{0} E L and 87 m above sea level). The plants were first cleaned by washing under running water and then air dried. The dried plant samples were cut into 2.5 x 1.5 cm chips prior to cooking. Some of the dry chip samples were taken and powdered in a willy mill to study the proximate chemical constituents of the plants.

Methods:

Morphological properties

Some of the morphological properties of the plants such as height, diameter, percentage of bark, percentage of wood, moisture content, density etc. were determined in the field as well as in the laboratory (Table 1).

Table 1: Morphological characteristics of the plants

Characteristics	*M. velutina*	*C. dichotoma*	*C. sativa*
Specific gravity of stem	0.28	0.35	0.42
Plant height, m	3.50	2.80	1.35
Stem diameter, cm	25	3.0	3.20
Length of the pseudostem, m	3.20	2.50	1.25
Weight of the whole plant, Kg	2.8	0.42	0.28
No of sheath in stem	12	-	-
Diameter of the core, cm	10	1.25	1.30
Bark / Sheath, %	35	20	22
Moisture content, %	87.55	79.5	75.5
Average constituents of the plant (% on O.D. basis)			
Sheath	45	-	-
Central core	35	-	-
Bark	-	22	22
Leaves/twigs	20	22	16
Wood	-	56	62

Table 2: Proximate chemical analysis of the plants

Particulars	Plant species		
	M. velutina	*C. dichotoma*	*C. sativa*
Solubility, %			
Cold water	2.5	2.3	4.2
Hot water	2.82	6.93	12.84
1% NaOH	26.5	33.1	27.6
Alcohol benzene	2.54	3.45	3.61
Cellulose, % (Cross & Bevan),	60.2	37.5	50.8
Pentosan,%	17.2	20.2	8.7
Lignin,%	16.0	16.2	4.8
Ash content,%	1.8	5.8	4.5
Silica,%	0.58	0.92	0.75

Table 3: Physical properties of pulp fibre

Particulars	*M. velutina*	*C. dichotoma*	*C. sativa*
Yield of unbleached pulp (%)	45	42	48.5
Yield of bleached pulp (%)	40.2	38.5	42.4
Kappa Number	27	30	32
Brightness of bleached pulp (%)	76	78.2	80.2
CED viscocity at 27 ^{0}C (Cp)	22.6	25.0	28.4
Average degree of polymerization (DP, Average)	275	300	320
Initial pulp freeness (^{0}SR)	15	17	16

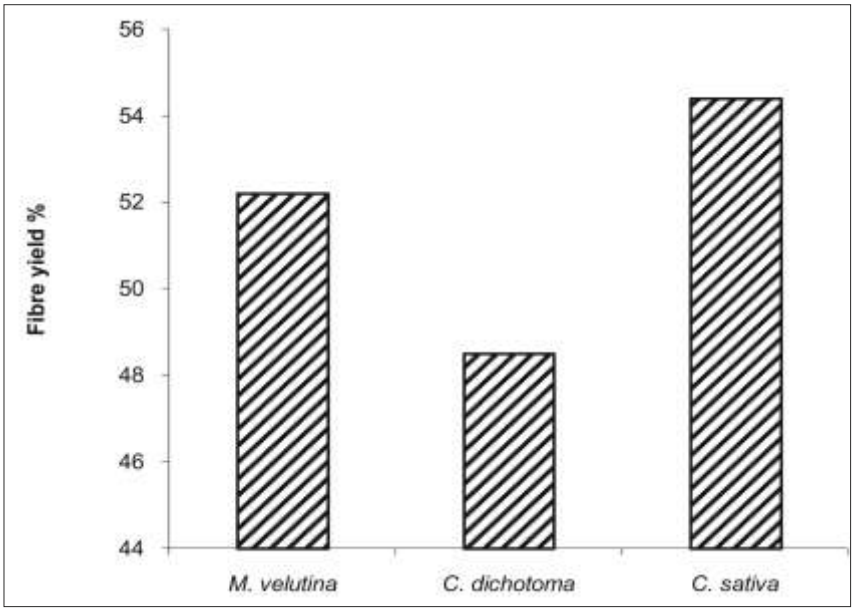

Figure 1: Fibre yield of different plant species

Proximate chemical constituents

Proximate chemical constituents of the plants were carried out as per the methods suggested by TAPPI (USA) (5). The chips of the plant materials were dried in an oven and then powdered in a Wiley mill. The powdered fraction passed through 40 BS mesh and retained on 60 BS mesh were taken for proximate chemical analysis. The results of the chemical analysis of the plants are shown table 2.

Pulp making

Pulping experiments of the plants were conducted in an electrically heated rotary stainless steel digester of 15 L capacity. 500 g O.D. chips were charged into digester along with the required quantity of chemicals maintaining bath ratio at 1:6. The cooking experiments were conducted by varying the cooking chemicals from 12 to 18% on the OD basis of raw material. The temperature was varied from 145-175°C at a fixed time period of 3 h. After cooking, the pulps were washed thoroughly with cold fresh water till it gets free from alkali. The pulp thus obtained was taken for determination of physical properties (Table 3).

Extraction of fibres from bark / outer sheaths

A separate experiment was conducted to extract the fibres from the outermost sheaths of *Clynogynae dichotoma* and *Musa velutina* and bark portion of *Cannabis sativa* by chemical process. Bark / sheaths were separated from the plants and cut into the size of 1.5 cm length. Digestion was carried out in a rotary digester maintaining the similar conditions of pulping as mentioned earlier. The digested bark / sheath fibres were properly washed with cold fresh water and air dried. The yield of the fibre were determined and presented in Figure 1.

Bleaching of pulp and fibre

Bleaching of pulp / bark fibres or sheaths were carried out adopting H-E-H bleaching sequence same as in the case of bleaching of wood pulp (4).

Brightness

The brightness of bleached paper sheet was determined by using an EIL Reflectance metre and the results were expressed as MgO=100 (Table 3).

Table 4: Morphological properties of the plant fibre

Properties		*M. velutina*	*C. dichotoma*	*C. sativa*
Fibre length, (L) mm	Range	2.80-0.42	3.25-0.40	3.70-0.45
	Average	1.25	1.35	1.52
Fibre width, (D) (µm)	Range	22-17	22-18	25-12.5
	Average	22	22	20
Cell wall thickness, (W), µm	Range	5.2-3	5.25-3.50	5.00-3.50
	Average	3.75	3.85	3.80
Lumen diameter, (d) µm	Range	16.5-6.8	17.5-7.5	17.10-8.50
	Average	15.2	15.0	15.50
Slenderness ratio, L/D		56.8	65.9	90.91
Runkel ratio, 2 W/d		0.44	0.51	0.56
Flexibility Co-efficient, (d/D x 100)		69.1	69.0	70.45
Ratio of twice cell wall thickness to fibre diameter		0.34	0.35	0.38
Shape factor		0.35	0.53	0.31

Figure 2: SEM of *M. velutina* fibre

Figure 4: SEM of *C. sativa* fibre

Fibre morphology

The morphological properties of pulp fibre i.e. length (L), diameter (D), wall thickness (W) and lumen diameter (d) of well-digested pulp were determined by using a Docuval photomicroscope (Zeol Japan). For determination of fibre dimensions, well digested pulp fibres were taken and disintegrated 15-20 minutes till the fibres get free from bundles. These bundle free fibres were taken and observations were made at different magnifications. The average values of twenty observations were recorded and presented in Table 4.

Scanning electron microscopic study

Disintegrated pulp fibres (O. D) were mounted on specimen holder with the help of electro conductive tap. The fibre samples were coated with gold in a ion sputter (ZFC 100 Zeol Japan) in low vacuum with a layer 150 to 200 nm. The observations were made in the electron microscope at an accelerating potential of 15 K V (Figure 2-4).

Figure 3: SEM of *C. dichotoma* fibre

Hand sheet making and testing

Both unbleached and bleached pulps obtained from the three plants were beaten separately in a laboratory valley beater at 1:2% consistency. The pulps were beaten up to 45 °SR (Schoper Reiglar) freeness and standard hand sheet of 60±1 gm^{-2} were made from the pulp stock in the British Standard laboratory hand sheet-making machine. The sheets were pressed in the hydraulic press and dried under pressure. The dried paper sheets were conditioned at 65±2% relative humidity and 27 ^{0}C for 2 h. The physical strength properties of paper sheets were tested as per TAPPI Standard Method (5) and presented in Table 5.

Blending of pulp with bark / outer sheath fibres

A separate experiment was conducted in the laboratory to evaluate the properties of paper from the blending of pulp and the outer sheath / bark fibre of *Clynogynae dichotoma Musa velutina* and *Cannabis sativa.* The fibres extracted from the outer sheaths / barks respectively were blended with the pulp at a ratio of 50:50. Both bleached and unbleached papers made from the blends of pulp and bark / sheath fibres were tested and the physical strength properties are presented in Table 6.

Results and Discussion

The morphological characteristics of the plant materials are shown in Table 1. The specific gravity of matured stem varied from 0.28-0.42 and the moisture content from 75.5-87.55%. The sheath constitutes 45% of the total weight of the plant recorded in *M. velutina* while bark constitutes 22% for *C. dichotoma* and *C. sativa.*

Table 2 represents the proximate chemical analysis of all the plants. It was observed that the important plant constituents viz. cellulose recorded 60.2% in *M. velutina* while 37.5 and 50.8% for *C. dichotoma* and *C. sativa* respectively. So also, the lignin content recorded 4.8-16.2% in all the three plant species. The pentosan content recorded highest 20.2% (*C. dichotoma*) and minimum 8.7% (*C. sativa*). *M. velutina* contained 17.2% pentosan in

Table 5 : Physical strength properties of paper sheets made from unbleached and bleached pulp

Plant material	Bulk density cc/g	Burst index (kPa m^{2}g^{-1})	Tear index (mN m^{2}g^{-1})	Tensile index (N mg^{-1})	Folding endurance (Double fold nos)
M. velutina					
Unbleached	1.45	5.20	9.3	58.65	250$^+$
Bleached	1.37	4.50	6.82	62.61	300$^+$
C. dichotoma					
Unbleached	1.48	4.70	10.5	60.82	400$^+$
Bleached	1.40	3.85	7.8	45.50	235$^+$
C. sativa					
Unbleached	1.50	5.80	11.77	62.67	320
Bleached	1.38	4.32	8.37	48.17	125$^+$

Table 6 : Physical strength properties of bleached paper made for the blends of pulp and bark / sheath fibres

Plant material	Bulk density cc/g	Burst index (kPa m^{2}g^{-1})	Tear index (mN m^{2}g^{-1})	Tensile index (N mg^{-1})	Folding endurance (Double fold nos)
M. velutina	1.40	5.40	9.22	74.80	360$^+$
C. dichotoma	1.44	4.62	8.90	54.00	300$^+$
C. sativa	1.42	5.80	9.85	56.60	190$^+$

the stem.

The physical properties of pulp fibres obtained from the plants are presented in the table 3. The unbleached and bleached pulp yield were recorded 48.5 and 42.4 % in *C. sativa* while *M. velutina* recorded 45.0 and 40.2% and *C. dichotoma* 42.0 and 38.5% digested under similar cooking conditions. There were a minor variation in Kappa number (27-32) and pulp brightness (76-80.2%). The viscosities of bleached pulp were recorded 22.6-28.4 Cp for all the plants.

Table 4 represents the fibre dimensions and morphological indices of the fibres. The fibre length recorded highest 1.52 mm in *C. sativa* followed by 1.35 mm in *C. dichotoma* and 1.25 mm in *M. velutina*. The average fibre width (D) were varied from 20-22 µm, cell wall thickness (W) from 3.75 µm (*M. velutina*) to 3.85 µm (*C. dichotoma*) and lumen diameter from 15.0 µm (*C. dichotoma*) to 15.5 µm (*C. sativa*). The runkle ratio (2W/d) and the shape factor (D^2-d^2/D^2+d^2) varied from 0.44-0.56 and 0.31-0.53 in all the three species. The fibre characteristics are collectively represented by runkle ratio and shape factor. The paper formation and physical strength properties are largely dependent on these properties. The results showed that the above three species are suitable for making good quality paper.

Figure 2-4 shows the SEM photomicrographs of *M. velutina C. dichotoma* and *C. sativa* fibres. In *M. velutina* the surface of the fibres were seen uneven with many distinct cracks. The fibrils were irregularly arranged with occasional pores. There were occasional cracks, with distinct pores visible in *C. dichotoma* fibres also. The fibrils were regular in arrangement. In *C. sativa* fibre no cracks were visible in the surface. Some void spaces were seen with occasional pores. Fibrils were irregular in arrangement.

The physical strength properties of paper sheets made out of unbleached and bleached pulps of above plants are shown in table 5. The results recorded for bulk densities of bleached paper sheets varied from (1.37-1.40 cc/g), burst indices 3.85-4.50 $Kpam^2g^{-1}$, tear indices 6.82-8.37 mNm^2g^{-1}, tensile indices 45.50-62.61 Nmg^{-1} and double fold 125^+ - 300^+ of bleached paper sheets made from the pulps of three species.

Table 6 shows the physical strength properties of bleached paper sheets made from the blends of bleached pulp and the bark / outer sheaths fibres prepared separately and mixed at 50:50 ratio. The physical strength properties of the bleached paper sheets were determined and Burst indices 4.62-5.80 $Kpam^2g^{-1}$, Tear indices 8.90-9.85 mNm^2g^{-1} and Tensile indices 54.00-74.80 Nmg^{-1}. All the physical strength properties of paper were found increasing in all the plants.

Conclusion

It can therefore be concluded that the plant species under the present investigation would be ideal source for making paper grade pulp. The physical strength of paper may further be enhanced if the bark / sheath fibres are cooked separately and blended with the pulp.

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