Evaluation Of Banana Pseudostem Based Fibre As Pulp And Paper Making Raw Material

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ABSTRACT

An ever increasing demand for pulp and paper *vis-a-vis* decline in forest based raw material has compelled the industry, scientists and planner to find out suitable supplement or substitute for the raw material. Banana being grown in vast area (7.0 lakh ha) in India, it generates huge quantity of waste biomass in the form of pseudostem (60 to 80 t/ha), leaves, suckers etc. In order to utilize this waste for developing value added products, a project entitled "A Value Chain on Utilization Pseudostem for Fibre and Other Value Added Products" was sanctioned under NAIP (ICAR), New Delhi. The results of studies conducted under this project indicate that banana pseudostem fibre can be used as raw material for pulp and paper industries. Proximate chemical analysis finds the suitability of this fibre as paper making raw material. Pulping characteristics of banana pseudostem fibre were also investigated using soda pulping and CEpHD bleaching sequence. These studies were carried out with unbleached pulp of ~15 kappa no. aiming final pulp brightness of ~88 % ISO. The chemical consumption to achieve the final optical properties is lesser with good viscosity of pulp (12.6 cp). The pulp was also evaluated for physical strength properties of both unbleached and bleached pulp. The higher double fold, tear factor and burst factor indicates its suitability for making speciality papers like greaseproof, parchment, cheque and currency paper etc.

Key Words: Musa *Parabisica*, Banana pseudostem, Pulping, Bleaching

Introduction

The shortage of pulp wood is caused by increase in demand of pulp and paper, coupled with decline in forest based raw material. Because of this situation, industry, scientists and planner have started search for suitable alternative raw material. As a results of their efforts, some of the agro waste like baggase, crop residue etc. are already being used in paper industry. Among the agro waste, use of banana waste in paper industry has not been explored so far. Banana (Musa spp.) the second largest fruit crop in world is grown in tropical and subtropical regions. Scientific classification of banana plant is, *Kingdom: Plantae; Class: Liliopsida; Order: Zinberles; Family: Musacae; Genus: Musa; Species: parabisica*. It is cultivated in almost all the states and it occupies around in 7.1 lakh hectars area with an annual production of 13.2 million tones. After harvesting of fruit, the pseudostems are cut and usually left in the field or removed from field by spending about 8000- 10000 Rs/ha. In general, about 60 to 80 t/ha biomass as waste in the form of pseudostem is generated and its disposal is major problem for the farmers. In order to use banana pseudostem for developing value added products a project entitled "A Value Chain on Utilization of Banana pseudostem for Fibre and Other Value Added Products" was sanctioned under NAIP (ICAR), New Delhi with Navsari Agricultural University, Navsari (Gujarat) as lead Centre and Central Institute for Research on Cotton Technology (ICAR), Mumbai (MS), Man Made Textiles Research Associations, Surat (Gujarat) and J K Paper Mills, Songadh (Gujarat) as partners. The value added products i.e fibre, yarn, fabrics, MCC, vermicompost, liquid fertilizer, quality papers, candy and pickles developed/prepared using banana pseudostem by the scientists of the Consortium. In this project, it was envisaged to standardize the processes for preparing quality papers using fibres extracted from banana pseudostem. Apart from quality paper, one Handmade Paper and Board Unit (Figure 2) has been commissioned at NAU, Navsari with technical support of JK Paper Ltd. In this unit, variety of paper and board has been prepared using banana fibre, scutcher, cotton rags, waste paper and straws as a mix. The same material has been used for preparation of different articles like file cover, pads, art paper, printing paper and folders etc. The processes standardized for preparing quality paper are presented here.

MATERIALS AND METHODS

For our study we used banana pseudostem fibre extracted by NAU, Navsari, Gujarat.

Extraction of fibre from pseudostem:

After harvesting the fruits and leaves, pseudostem is cut near to the ground level. CIRCOT Mumbai developed raspador machine (Figure 1), which is used for extracting fibres from banana pseudostem easily and quickly. Before extraction of fibre one has to separate the sheaths from the pseudostem by splitting it. For this purpose NAU, Navsari developed pseudostem cutter machine which facilitate the speedy splitting of pseudostem in to 2 or 4 halves. Lengthwise strips prepared were scraped to yield strands using raspador units for separation of fibres. The fibres were then washed and rinsed

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FIGURE 1: RASPADOR MACHINE

FIGURE 2: HANDMADE PAPER PLANT AT NAU, NAVSARI

in clean water and air dried.

Proximate analysis:

Sample for proximate analysis was prepared by cutting fibre into small pieces followed by grinding with mortar and pestle. Grounded material was passed out on 40 mesh size as per standard and was used for analysis. The results of proximate analysis are given in Table 1.

Pulping:

Pseudostem fibre extracted as mentioned above was cut into small size pieces (35 cm). Soda pulping of fibre was carried out in an electrically heated stainless steel rotary autoclave digester with polyethylene glycol bath having thermostatically controlled system. A number of experiments were performed to optimize the pulping conditions to achieve a Kappa no. ~15. After cooking the digester was blowout (depressurized) and pulp and spent cooking liquor was separated and collected. Subsequently pulp was washed over 300 mesh screen with warm water for alkali removal. Pulp fibres were deliberated in a laboratory agitator followed by Sommer vile screening using 1.5 mm slot. Accepted and rejected portion of pulp from screen was quantified for screened yield (Table 2A). The black liquors were characterized for total solids, pH, residual alkali, organics, inorganics, silica, swelling volume index and viscosity (Table 3). The screened fraction was dewatered on a 300 mesh screen and stored in polythene bags for subsequent processing and analysis.

Bleaching:

All the pulps were bleached in multistage bleaching sequence (CEpHD) by employing the various bleaching conditions as mentioned in Table 4. Bleached pulps were characterized for brightness, viscosity, yield and Post Color Number.

Hand sheet formation and Testing:

Both unbleached and bleached pulps were beaten in laboratory valley beater upto 40° SR. 60 gsm pulp hand sheets were prepared for both pulps in British Standard Laboratory Hand sheet Making Machine, followed by pressing and drying. The hand sheets were conditioned at 65 % relative humidity,

TABLE 1: PROXIMATE CHEMICAL ANALYSIS OF PSEUDOSTEM BASED FIBRE

Particulars	Results
Bulk density, kg/m^3	35.6
Hot water solubility, %	11.0
Cold Water solubility, %	3.4
A-B Extractive, %	7.2
1 % NaOH Solubility, %	29.5
Acid Insoluble Lignin, %	15.6
Holocellulose, %	83.5
α-Cellulose ,%	73.9
Pantason, %	10.0
Ash, %	5.0
Silica ,%	2.0

TABLE 2A: PULPING CONDITIONS

Particulars	Values			
Soda Charged (%)	14	15	16	17
Cooking temperature (°C)	160	160	160	160
Time to temperature 160°C (min)	60	60	60	60
Time at cooking temperature (min)	90	90	90	90
Bath ratio	1:5	1:5	1:5	1:5
Kappa no.	21.6	15.0	12.6	10.8
Reject (%)	3.5	3.1	2.8	2.6
Screened Yield (%)	64.5	56.5	52.6	50.9
Unbleached pulp brightness, %ISO	25.9	28.7	31.2	33.2
Black Liquor Properties				
pH	9.9	10.2	10.6	11.0
RAA, gpl	2.5	3.8	4.2	4.5
Total Solid, %	9.4	9.8	10.3	10.7

TABLE 2B: EFFECT OF TEMPERATURE ON PULPING

Particulars	Values		
Soda Charged (%)	15	15	15
Cooking temperature (°C)	150	160	165
Time to temperature 160°C (min)	60	60	60
Time at cooking temperature (min)	90	90	90
Bath ratio	1:5	1:5	1:5
Kappa no.	22.7	15.9	11.7
Reject (%)	2.8	2.5	2.3
Screened Yield (%)	63.9	57.5	52.2
Unbleached pulp brightness, %ISO	25.5	28.5	31.5

TABLE 3: BLACK LIQUOR ANALYSIS

Particulars	Results
pH	10.2
RAA (gpl)	3.8
Total Solids (%)	9.8
Organics (%)	61.4
Inorganics (%)	38.6
Viscosity at 80 °C Spindle : 1 and rpm: 50 (cp)	4.5
GCV (K Cal/kg)	3109
Swelling volume index (ml/gm)	18.0
Silica as SiO2 (%)	1.12
R2O3 (%)	0.63

at 27° C for 4 hrs and then tested for physical properties using standard methods which are mentioned below (Table 6). **Analytical Techniques:**

Hot and Cold water solubility of raw materials was determined as per Tappi Test Method T 207 cm-99

1% NaOH solubility of raw materials was determined as per Tappi Test Method T 212 om-02

AB extractives was determined as per Tappi Test Method T 204 cm-97

Cellulose content was determined as per T 203 cm-99

Klason lignin was determined as per Tappi Test Method T 222 om-02

Holocellulose was determined as per CPPRI TM 1-A-9

Ash and Silica was determined as per CPPRI TM 1-A-5 & A-6

Pentosan was determined as per CPPRI TM 1-A-11

Moisture content of pulp was determined as per Tappi Test Method T 210 cm-86

Kappa number of unbleached pulp was determined as per Tappi Test Method T 236 cm-85

Free alkali, organic, inorganics, silica, sulphate, chlorides and mixed oxides in black liquor was determined as per Tappi Test Method T 625 cm-85

Swelling Volume Ratio of black liquor was determined as per CPPRI TM III-A-12

Viscosity of black liquors using Brookfield digital viscometer was determined as per Venkatesh, V. and Nguyen, X.N., Evaporation and concentration of black liquor, In: Chemical recovery in the alkaline pulping processes, Tappi press (1985)

Brightness of pulp was determined as per ISO Brightness Metre (L&W Elrepho) as per the instructions given in manual

Viscosity, an indicator of cellulose molecule chain length was determined by dissolving the pulp in cupriethylenediamine (CED) solution and measuring the viscosity of a 0.5% solution with an Ostwald Viscometer (Tappi Test Method T 230 om-82)

Handsheets for physical strength testing were formed as per Tappi Test Methods T 205 om-85

Strength properties of hand sheets were tested according to Tappi Test Method T 220 om-88

Fiber length and fiber diameter of pulp fibers was measured as per Tappi Test Methods at PAPRI

Fiber classification of pulp fibers was measured as per Tappi Test Method T 233 cm-82

Grammage of handsheets was measured as per Tappi Test Method T 410 om-02

Burst factor of handsheets was measured as per Tappi Test Method T 403 om-02

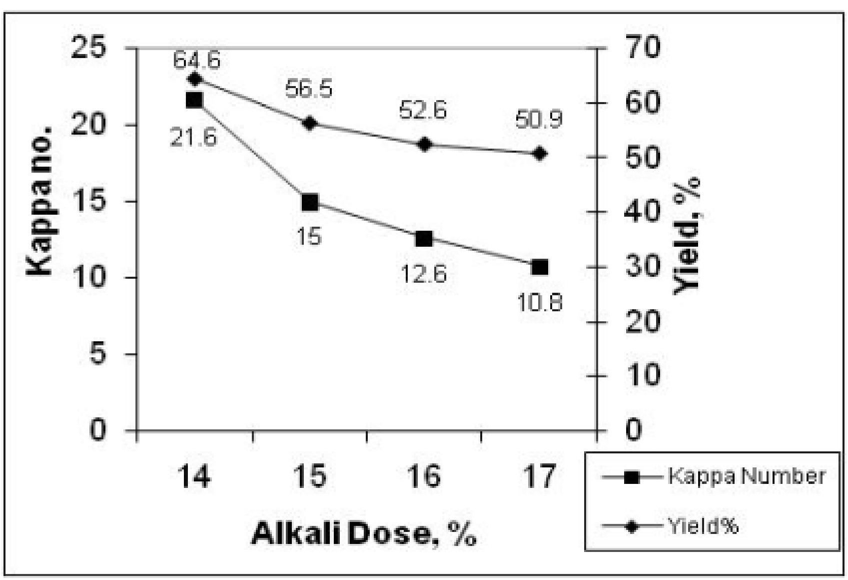
Tear factor of handsheets was measured as per Tappi Test Method T 414 om-98

Tensile strength (Breaking length) of handsheets was measured as per Tappi Test Method T 494 om-01

TABLE 4: PULP BLEACHING

Parameter	Banana fibre pulp
Kappa no.	15.0
C stage	
Kappa factor	0.17
Cl_2 added (%)	2.5
Cl_2 consumed (%)	2.48
Final pH	2.1
Consistency (%)	3.0
Temp. (°C)	Ambient
Time (min.)	30
E_P stage	
NaOH added (%)	1.5
H_2O_2 added (%)	0.7
Consistency (%)	10.0
Temp. (°C)	70
Time (min.)	120
Initial pH	11.3
Final pH	10.8
Kappa No.	2.0
Brightness (% ISO)	57.6
Viscosity (cp)	20.9
H stage	
Hypo added (%)	1.5
Hypo consumed (%)	1.45
Consistency (%)	10.0
Temp. (°C)	45
Time (min.)	120
Final pH	7.5
Brightness (% ISO)	80.7
D stage	
ClO_2 added (%)	0.7
ClO_2 consumed (%)	0.65
Consistency (%)	10.0
Temp. (°C)	80
Time (min.)	180
Final pH	3.0
Brightness (% ISO)	88.0
Viscosity (cp)	12.6
Pc No.(no)	1.5
Bleached pulp yield (%)	50.0

FIGURE 3: EFFECT OF ALKALI DOSAGE ON KAPPA AND UNBLEACHED YIELD



Double fold of handsheets was measured as per Tappi Test Method T T 511 om-02

Results And Discussion

Results of proximate chemical analysis are presented in Table 1. Bulk density of banana pseudostem based fibre is low 35.6 kg/m3. Hot and cold water solubility is 11.0, 3.4% and AB extractive is 7.2%, respectively. The hot water and alcohol benzene solubility values indicate the presence of considerable content of light weight aliphatic and aromatic compounds. Higher extractive content can be explained with higher content of polyphenols. 1% caustic solubility is 29.5% which exhibits fibres suitability as raw material for pulp and paper and can be considered adequate. The low molecular weight polysaccharide implies that pulping chemical charges should be moderate. Lower lignin content (15.6 %) is desirable because it hinders the formation of fibre-to-fibre bonds in paper and as such decrease in paper strength. The holocellulose and cellulose are 83.5% and 73.9 %, respectively. Cellulose is important with respect to paper properties because the attraction between cellulose molecules of different fibre surface leads fibre-to-fibre bonding in paper. Overall results revealed a moderately lower content of non-cellulosic materials and have potential for greater yield and pulp quality. The pentosan content (10.0%) may also import the grease proof properties. The ash and silica content in banana based fibre is 5.0% and 2.0% respectively. The reported results indicate the suitability of banana pseudostem fibre for pulp and paper making.

Soda Pulping results at different dosages (14-17%) of alkali allowed for the achievement of the pulp with different kappa number at different yields and residual alkali at the end of the cook (Table 2A). The requirement of active alkali to reach kappa number of ~15 is 15.0% for banana pseudostem fibre pulp. Screened yield is 56.5% at a optimized kappa no. of 15. Total solid content in black liquor is 9.4 to 10.7% and RAA 2.5 to 4.5 gpl with 14 to 17% alkali dosing. The organic matter is 61.4% and inorganic matter is 38.6% in banana fibre spent cooking liquor (Table 3). The various other liquor quality parameters are also reported in the same table. The impact of temperature on soda pulping, pulp quality and yield is significant (Table 2B, Figure 4).

Unbleached pulp of kappa no. 15 was used for multi stage bleaching (CEpHD) sequence to achieve the target of 88 % ISO brightness. The bleachability of banana fibre is good

FIGURE 4: EFFECT OF TEMPERATURE ON KAPPA AND UNBLEACHED YIELD

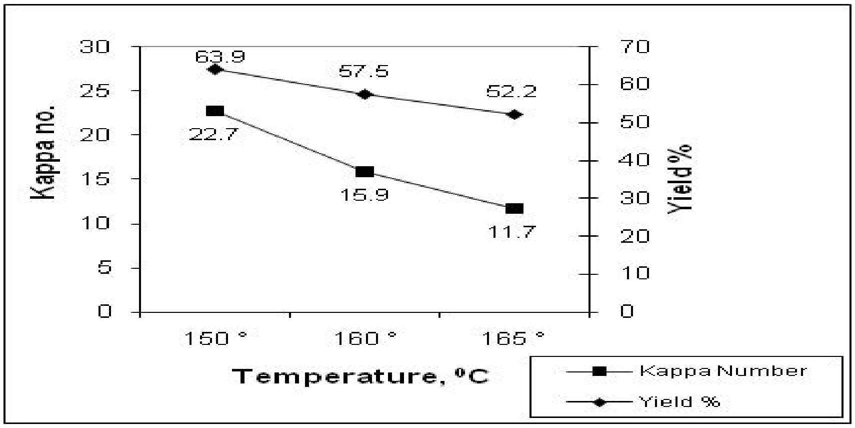


TABLE 5: BAUER-MCNETTCLASSIFICATION OF PULP (UNBEATEN)

Sample detail	Values (%)				
	+30	+50	+100	+200	-200
Banana Pseudostem (Unbleached)	77.5	4.6	5.1	4.0	8.8
Banana Pseudostem (Bleached)	75.9	4.5	4.3	3.4	11.9

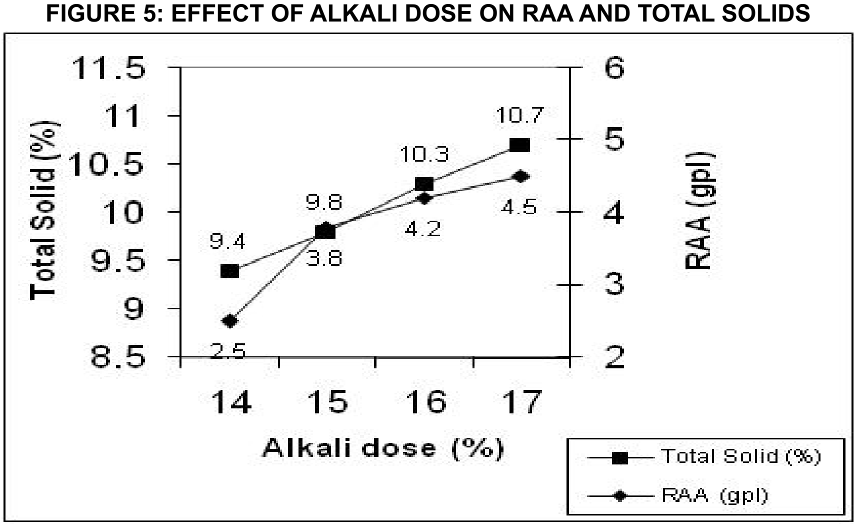
TABLE 6: STRENGTH PROPERTIES OF UNBLEACHED AND BLEACHED PULP

Particulars	Unbleached Pulp	Bleached Pulp
Final freeness (°SR)	40	40
Basis weight (gsm)	60	60
Bulk (cc/g)	1.30	1.27
Tear Factor	86	84
Burst Factor	88	80
Breaking Length (metre)	6678	5931
Double Fold (no.)	2580	1389
Strength Index	2956	2764

TABLE 7: FIBER MORPHOLOGY (PAPRI)

Parameters	Value
Fibre length, length weighted, (mm)	1.44
Fibre diameter, length weighted, (micron)	18.9

FIGURE 5: EFFECT OF ALKALI DOSE ON RAA AND TOTAL SOLIDS



(Table 4). The bleached pulp yield at 88% ISO brightness is 50.0% and viscosity 12.6 respectively. The pulp obtained was having good optical properties along with higher strength and less colour reversion.

The physical strength properties of both unbleached and bleached pulp are recorded in Table 6. The unbleached and bleached pulp properties are more or less comparable in terms of bulk and tear factor, however burst factor is 88 and 80, respectively. Breaking length in unbleached and bleached pulp is 6678 and 5931 metre, and double fold 2580 and 1389, respectively. The overall strength index is 2956 and 2764 in case of unbleached and bleached pulps. These properties indicate that the pulp quality is adequate for speciality grades of paper i.e greaseproof, cheque and currency paper etc.

Fibre fraction (Bauer-McNett) analysis results are given in table 5. The results showed that both unbleached and bleached pulp contains good fibre length 77.5 and 75.9% fibre fraction in +30 mesh respectively. The results revealed lower -200 fractions 8.8 and 11.9% respectively which lead to less fines and higher pulp yield. Fibre length and fibre diameter is 1.44 mm and 18.9 micron respectively for bleached banana pulp (Table 7).

Conclusion

From the results, it is concluded that banana pseudostem fibre can be a potential source of raw material in pulp and paper industry. This will not only resolve waste disposal problem of banana pseudostem, but farmers can realize additional income from waste. Banana pseudostem fibre gives higher pulp yield and brightness with less chemical consumption. This extracted fibre pulp seems suitable as a mix for preparing special grades of paper i.e parchment, greaseproof, Cheque and Currency paper. Due to lower bulk transportation cost would be higher as compared to other raw materials. Fibre extraction cost from pseudostem is high due to manpower intensive which increases the pulp manufacturing cost. Further efforts are required to reduce the cost of fibre from banana pseudostem and NAU is already working with Consortium Partner's to reduce the cost of fibre extraction by means of technology upgradation and scale up of the processes.

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