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RESEARCH REPORT NO. 6

SUITABILITY OF BANANA STEMS FOR PAPERMAKING

Based on the work

of

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Technical guidance

by

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NOTE

The findings given in the report are those considered appropriate at the time of its preparation when only laboratory results were available. The final findings are to be confirmed on pilot plant scale. All the units used in this report are SI units. Conversion factors for old units are given in Annexure I.

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ABSTRACT

Soda pulping experiments were carried out on dried banana and freshly cut banana pseudo stems. Different methods for fibre separation from the pithy material like acid hydrolysis of the chips prior to cooking and post hydrolysis of the pulp from soda cook were tried. Pulp is slow, draining and of low yield, making the banana stems economically unsuitable for paper-making

SUITABILITY OF BANANA STEMS FOR PAPER MAKING

1 Introduction

Investigations were carried out to evaluate the suitability of banana stems for paper making. Earlier work carried out on banana stem (1,2) showed they are unsuitable for large-scale paper manufacture due to their very high moisture content, poor and uneven sheet formation and slow drainage properties. Studies were done on dried banana pseudo stems received from "Andhra Pradesh Paper Mills Ltd.," Rajahmundry. Freshly cut banana pseudo stems procured locally were also used. The results of those investigations are presented in this report.

2. Agronomical data

Banana belongs to genus Musa, which is a genus of perennial tree-like herbs widely distributed in most tropics from Africa in the West to the Polynesian Island in the East. In India about 14 species have been recorded and the area under banana cultivation has been estimated at 383,000 acres. Two third of this area lies in Kerala, Tamil Nadu, Karnataka, Maharashtra and Andhra Pradesh. It is cultivated mostly in tropical belt. In India, most satisfactory conditions for its cultivation are found along the coastal areas of Kerala, Tamil Nadu, Maharashtra and West Bengal. The plant grows best in rich well-drained soil with ample moisture and decayed organic matter. It can flourish also on light sandy or gravelly soil as well as stiff but well-drained clays, if the soil is fertile and facilities for irrigation are available.

The fibre is located primarily adjacent to the outer surface of the leaf sheath. Each leaf sheath consists in cross section of three layers, the outer fibrous layer, the middle containing a small quantity of fine white fibres and the inner layer which contains no fibre at all.

The fibre consists of strands ranging in length from 0.9 to 2.7 m. Each strand is made up of bundles of fibre cells 3 to 12 mm long and 16 to 32^{u} diameter, irregularly round or oval with tapering ends. The fibres contain 60-70% cellulose and resembles jute in Chemical composition (3).

3. Experimental

3.1 Pulping

All pulping experiments were carried out in series digester consisting of 6 bombs each of 2.5 litres capacity, rotating in electrically heated polyethylene glycol bath. In each bomb 150 gm. o.d. raw material was taken. At the end of the cooking period, the bombs were removed from the bath and cooled by immersion in a water tank. Each bomb was opened and spent liquor was collected after filtering through nylon cloth. The pulp was disintegrated in cold water and then washed thoroughly on nylon cloth as filtration was very slow.

Kappa number of pulp, spent liquor analysis, pulp evaluation studies were carried out as per standard methods (4). Pulping data and strength properties are presented in Tables 1 to 4.

4. Results and discussions

4.1 Proximate analysis

The proximate analysis carried out on mill and freshly cut banana stems is presented in Table 5. Bulk density of banana chips is very low (34.6 kgs/m^3). Solubilities in alkali and water are high. Pentosan and ash contents are comparatively lower than those for other agriculture residues.

4.2 Studies on Mill banana stems

Initially soda pulping was carried out on the above raw material with 5% NaOH under the cooking conditions given in Column I of Table 1. But the material remained uncooked and

the pH of the spent liquor was below 7. The pulp contained too much fine pithy material making the filtration difficult. Different methods were tried to separate fibres and pithy material from raw material.

4.2.1 Different methods of fibre separation

a. Fibre separation by passing through disc refiner

The chips were soaked overnight in water, then passed through Sprout Waldron disc refiner at high clearance to loosen the pith and the slurry was washed on 20 mesh and then dried. Soda pulping was carried out with 7.5% NaOH at 160°C for 3 hours. The results are given in Column I of Table 1 and the strength properties are given in Table 2. Even with 7.5% chemical, pulp was very dark, specky and shivy with high Kappa number (83.0). The freeness of the pulp was quite low and pulp possessed poor strength properties. Tear index was quite low.

b. Fibre separation at low consistency in valley beater

Fibre separation of the dried banana was carried out at low consistency (about 1%) in valley beater, at pH 2.5-3 by adding HCl, for about 30 minutes. The slurry washed on 20 mesh screen and the material passing through screen was taken as pith. Pith content of banana found by the above method was 22.0%. The banana fibre retained on 20 mesh was dried and soda pulping was carried out with 12.5% NaOH at 160°C for 2 hours. The results are given in Column III of Table 1 and strength properties in Table 2. The strength properties are very low.

c. Fibre separation by acid hydrolysis

Fibre separation was carried out by acid hydrolysis prior to cooking, on chips and also by post hydrolysis on pulp. Prehydrolysis was carried out with 5% HCl, at

120°C for one hour maintaining 1:7 bath ratio, keeping the concentration of HCl at 7 g/l. After prehydrolysis, the chips were washed free of acid and then soda pulping was carried out using 12.5% NaOH at 160°C for two hours. The cooking conditi ns and results are given in Column V of Table 1 and strength properties in Table 2. Soda pulp obtained by cooking banana chips with 12.5% NaOH, was subjected to acid hydrolysis with 8.75% HCl and 5% HCl on pulp keeping two hours at 70°C at 8% consistency. The results are given in Columns IV, VI and VII of Table 1, and strength properties in Table 2. From the results the following observations could be made.

The pulp yield from soda cook was low. The pulp was quite slimy, dark in colour, containing pith in the form of powdery material clogging the filtering cloth and resulted in slow draining. The pulp obtained by prehydrolysis cook, was comparatively lighter in colour and relatively free of slimy nature and pith. The overall yield was further reduced to 33%. There was no improvement in strength properties. Post hydrolysis of the pulp with 8.75% HCl on pulp (7 gpl concentration of HCl as in prehydrolysis cook) resulted in very low yield of around 30% and strength properties were comparatively better than prehydrolysis pulp. Reducing the concentration of HCl to 4 g/l (5% HCl on pulp) yields a pulp of good strength properties with not much degradation. Post hydrolysis of the pulp seems to be preferable to prehydrolysis for removal of pith.

4.3 Studies on freshly cut banana stems

Freshly cut banana stems were collected. Sheaths were peeled off and central hard core rejected. Dryness of banana

stems = 12%. The sheaths were crushed and dewatered by passing through paper machine rolls repeatedly. The loosened pith was removed by retting the crushed material and hammering. The lengthy fibres were cut to 1 inch length and dried. Pulping experiments were carried out on the above depithed banana chips. Soda pulping was carried out varying the chemical dosage from 7.5 to 15%. Cooking conditions are given in columns I to IV of Table 3 and strength properties in Table 4. Results of prehydrolysis and post hydrolysis treatments carried out on the depithed banana are given in Columns V to VIII of Table 3. Prehydrolysis treatment reduced the yield from 45% to 32% and severe degradation of the fibre was evident from the low strength properties though pulp was of light colour and free from pith. Post hydrolysis treatment, though was certainly better than prehydrolysis treatment, the improvement in strength properties was not appreciable. Fibre separation carried out in valley beater at low consistency at 2.5-3 pH, had not yielded pulp of good strength properties on soda pulping. The pulping results are given in Column IX of Table 3 and strength properties are given in Table 4.

5. Conclusions

i/ Banana pseudo stem contains about 22% pith. Pulping as such is not advisable as the resulting pulp is quite slimy and contains lot of pithy material and is slow draining.

ii/ Removal of pithy material by prehydrolysis is not quite effective, resulting in considerable degradation of the pulp and low strength properties.

iii/ Post hydrolysis with lower concentration of HCl, than used in prehydrolysis, results in comparatively better strength properties.

iv/ The overall yield of fibre on fresh banana is very low.

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TABLE

PULPING DATA OF MILL BANANA STEM

Particulars	I as such	II Depithed	III Depithed (in-valley beater)	IV as such	V		
Prehydrolysis stage							
HCL % on raw material	-	-	-	-	5.0	-	-
Chips to liquor ratio					1:7		
HCl concentration in the liquor g/l					7.0		
Temperature °C					120		
Time, min.					60		
Residual HCl, g/l					-		
Pulping stage							
Chemical as NaOH, %	5.0	7.5	12.5	12.5	12.5	12.5	12.5
Chips to liquor ratio	1:6	1:7	1:7	1:7	1:7	1:7	1:7
Cooking temperature °C	160	160	160	160	160	160	160
Cooking schedule							
Raising time to 100°C, min.	30	30	30	30	30	30	30
From 100°c to 160°C, min.	90	90	90	90	90	90	90
At 160°C, min.	100	180	120	120	120	120	120
Post hydrolysis stage							
HCl % on pulp	not	-	-	-	-	8.75	5.0
Pulp consistency, %	cooked					8.0	8.0
HCl concentration in the liquor g/l						7.0	4.0
Temperature, °C						70	70
Time, min.						120	120
Residual HCl, g/l						3.0	3.0
Total yield, %		56.7	58.7	42.8	32.8	29.3	37.5
Kappa number of the pulp		83.0	-	-	-	-	-
Spent liquor							
pH	6.5	7.8	11.4	9.7	10.2	-	
Total solids, % w/w	8.3	5.7	7.6	8.1	6.1		
Residual NaOH, g/l	Nil	Nil	4.3	1.0	1.4		

TABLE 2

STRENGTH PROPERTIES OF UNBLEACHED MILL BANANA PULPS

Sample particulars	PFI rev.	Freeness	D. time (s)	Apparent density g/cm^3	Burst index $kPam^2/g$	Tensile index N.m/g	Stretch %	Fold Kohler Molir. log.	Tear index $mN.m^2/g$	Air res. Gurley s/100 ml
Pulp from II	0	160	29.4	0.64	2.10	34.0	3.5	1.92	5.25	1800
	500	40	100	0.66	2.55	43.5	4.6	2.60	4.50	1800
Pulp from III	0	290	11.4	0.56	0.65	21.5	2.4	0.77	4.60	16.4
	500	70	62.2	0.58	1.55	34.0	3.8	1.34	4.25	1800
Pulp from IV	0	60	106	0.64	2.70	43.5	1.9	2.49	5.50	1800
Pulp from VI	0	120	51.2	0.75	3.65	59.0	2.1	2.77	7.30	1800
	5000	30	83.4	0.72	4.55	69.0	2.4	3.08	5.95	1800
Pulp from VII	0	240	15.2	0.67	6.50	80.0	3.0	3.48	7.70	1800
	2000	135	28.0	0.81	7.25	82.5	3.3	3.49	6.05	1800

TABLE 3

PULPING DATA OF FRESHLY CUT BANANA STEM

Particulars	I	II	III	IV	V	VI	VII	VIII	IX
Prehydrolysis stage									
HCl, % on raw material	-	-	-	-		5.0	-	-	-
Chips to liquor ratio						1:7			
HCl concentration in the liquor g/l						7.0			
Temperature °C						120			
Time, min.						60			
Residual HCl, g/l						2.67			
Pulping stage									
Chemical as NaOH, %	7.5	10.0	12.5	15.0	12.5	12.5	12.5	12.5	12.5
Chips to liquor ratio	1:8	1:8	1:8	1:8	1:7	1:7	1:7	1:7	1:7
Cooking temperature °C	160	160	160	160	160	160	160	160	160
Cooking schedule									
Raising time to 100°C, min.	30	30	30	30	30	30	30	30	30
From 100°C to 160°C, min.	90	90	90	90	90	90	90	90	90
At 160°C, min.	180	180	180	180	120	120	120	120	120
Post hydrolysis stage									
HCl % on pulp	-	-	-	-	-	-	0.75	5.0	
Pulp consistency, %							8.0	8.0	
HCl concentration in the liquor g/l							7.0	4.0	
Temperature °C							70	70	
Time, min.							120	120	
Residual HCl, g/l							2.6	0.25	
Total yield, %	52.1	47.7	45.0	44.2	44.6	32.0	36.8	40.3	50.0
Kappa number of the pulp	70.4	54.3	38.5	30.3	-	31.3	36.3	33.0	-
Spent liquor									
pH	9.2	10.8	12.4	12.7	11.8	11.9	-	-	11.2
Total solids, % w/w	6.3	6.8	7.2	7.8	8.57	4.73			8.0
Residual NaOH, g/l	0.2	0.8	2.2	4.6	2.87	2.26			1.25

TABLE 4

STRENGTH PROPERTIES OF UNBLEACHED PULPS FROM FRESHLY CUT BANANA STEM

Sample particulars	PFI rev.	Freeness CSF	D. time (s)	Apparent density g/cm^3	Burst index kPam^2/g	Tensile index N.m/g	Stretch %	Fold Kohler Molin log	Tear index mN.m^2/g	Air res Gurley s/100 m
Pulp from I	0	175	41.5	0.64	3.75	57.5	4.2	3.18	8.50	1600
	500	85	79.6	0.66	4.85	58.0	4.4	3.25	9.10	1800
Pulp from II	0	235	38.1	0.59	4.05	52.0	2.4	3.19	9.50	1800
	500	90	69.3	0.65	4.15	63.0	3.7	3.43	8.95	1800
Pulp from III	0	110	34.8	0.69	5.30	65.0	4.6	3.28	7.00	1800
	500	110	51.2	0.73	5.60	72.0	5.1	3.40	7.30	1800
Pulp from IV	0	145	37.7	0.70	4.65	65.5	5.2	3.36	7.80	1800
	500	100	58.5	0.71	5.35	71.0	5.4	3.38	7.15	1600
Pulp from VI	0	525	5.87	0.56	0.30	19.0	0.8	-	2.2	53
	2000	*115	138	0.84	1.50	34.0	2.4	0.48	1.9	1800
	4000	185	328	0.86	1.80	35.0	2.2	0.70	1.8	1800
Pulp from VII	0	320	16.3	0.65	4.60	60.0	4.3	2.87	9.60	1800
	1000	100	14.6	0.69	6.65	67.5	4.8	3.48	7.60	1800
Pulp from VIII	0	365	54.7	0.70	5.20	64.0	4.9	3.21	8.85	1800
	1000	110	66.0	0.75	6.50	77.0	5.0	3.52	7.35	1800
**Pulp from IX		105	58.0	0.66	2.25	49.5	2.6	2.72	4.1	1800
		50	66.0	0.67	2.90	54.0	3.0	2.60	4.0	1800

*False CSF

**Evaluated in valley beater.

TABLE 5

PROXIMATE ANALYSIS OF MILL AND FRESHLY CUT BANANA STEMS
(All results expressed on % o.d. basis)

Sl No	Sample reference	Water solubility	ALC:BEN solubility	N/10 NaOH solubility	Holo cellulose	Klason lignin	Acid soluble lignin	Pentosan	Ash
1.	Unpithed Mill banana stem	24.0	3.2	42.8	68.2	13.2	1.4	13.2	11.4
2.	Depithed Mill banana stem	6.2	3.1	34.1	69.8	15.2	1.8	16.0	4.6
3.	Freshly cut depithed banana stem	13.7	1.3	43.8	-	13.2	1.3	12.1	3.2
4.	Pith from freshly cut banana stem	19.2	1.3	51.8	-	11.0	1.4	11.2	5.9

Bulk density of mill banana stem chips : 34.6 kgs/m^3
(on o.d. basis)

ANNEXURE I

CONVERSION FACTORS FROM SI TO OBSOLESCENT (KGS) UNITS

ISO (International Organisation for Standardisation) methods were used in this investigation for pulp and paper testing. All results and calculations are expressed in SI units (Systeme International d'Unites) as this system was adopted in India,

Some basic SI units		Conversion to Obsolescent units
Mass	: Kg, g	
Length	: m	
Area	: m^2	
Time	: second (s)	
Force	: Newton (N) milliNewton (m^N)	1N = 0, 102 kp
Pressure	: Pascal (Pa), Kilopascal (kPa)	1Kpa = 0.0102 kp/cm^2
Dynamic viscosity Pa.s (Pascal second)		1P = 0,1 Pa.s 1cP = 10^{-3}Pa.s

Conversion of paper testing data :

From SI unit	To obsolescent unit	Multiply by
Tensile index N.m/g	Breaking length km	0,102
Burst index kPa.m^2/g	Burst factor	10,2
Tear index mN.m^2/g	Tear factor	10,2
Scattering coefficient m^2/kg	Scattering coefficient ^{2}/g	10

For approximate indication tensile index can be converted to breaking length by dividing by 10, burst index converted to burst factor by multiplying by 10, tear index converted to tear factor by multiplying by 10.

It should be mentioned that in ISO standards the testing data are expressed on the basis of weight of conditioned sheet whereas other standards (e.g. APPITA) express results on basis of O.D. weight which makes exact conversion difficult.