Pulping and papermaking studies on nodes and internodes of bamboo (Bambusa arundinacea)

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As bamboo culm is not homogenous in physical, chemical and morphological characteristics, this project to study the pulping and papermaking characteristics, of its constituent parts i.e., internodal and nodal portions was taken up. The study reveals that, the internodal portion contains comparatively higher amounts of holocellulose and Alpha-cellulose and also gives comparatively higher yield and possesses higher strength properties, The nodal portion on the other hand, has comparatively higher inorganic constituents more lignin and it requires more chemicals for pulping. The unbleached pulp yield of the nodal portion was found to be lower by 4.4% at the same kappa number level, and it was observed that, this portion has a tendency to produce higher rejects on pulping, a fact very signficant from plant operation point of view. Also, the nodal portion has short fibre length, and some strength characteristics of its unbleached ana bleached pulps are comparatively lower, while double fold (MIT), tear foctor, and burst factor are poor.

Allhough, the internodal portion is far better, compared to nodal pors tion. in pulping and papermaking properties, because of the difficulties in mechanical separation of the two separate pulping and processing of these, woald not be feasible at present. Besides, the drop in quality and yield of the nodal pulp in the whole bamboo is not significant as to warrant serious efforts to separate and take out the nodal portions of the bamboo.

Introduction

Bamboo in the form of culms (stems) is the principal raw material for pulp and paper making in India. A bamboo culm is not homogenous anatomically, physically, morphologically, as compared to woody materials, as a source of cellulose fibres. It consists of two portions, namely the nodal portion, and the internodal portion. The properties of any raw material for pulp and papermaking, depend on its cellular constituents of fibres, and the latter, reflect to a large extent, in the final product, depending upon the operational conditions. The cheracteristics of the resultant paper are greatly affected by the species of bamboo utilised as a raw material (1, 2). So far, detailed and comparative studies on the nodal and the internodal portions of bamboo culms for pulping and papermaking, have not been reported in the literature. However, investigations on the chemical analyses of the tissues of nodal and internodal portions of bamboo (Dendrocalamus strictus) have been reported (3). This project was undertaken, to investigate the roles played by the nodal and internodal portions of bamboo, separately and together, on pulping and papermaking properties.

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Experimental :

Sound (fresh) dowga bamboos *(Bambusa arundinacea)* were collected from the mill yard. These culms were cut, into the rings of 2.5—3.0 cm in length, at the nodal and internodal

portions separately. Percentages of nodes and internodes were determined, on the basis of length, as well as weight. The average values for these and green volume density determinations, are as under :

	Nodes	Internodes
% on the basis of length	9.4	91.6
% on the basis of weight	20.0	80.0
Green volume density g/cc.	0.53	0.52

The rings of the nodal and internodal portions were cut separately at an angle of 45°, and chips were of about 3mm thickne .

i) Proximate chemical analysis :

For proximate chemical analysis, 250 g. of each of the above representative samples were powdered in Wiley Mill, till the powders passed through 60 mesh. These analyses were carried out as per Tappi Standards, for solubilities in cold and hot waters, 1% sodium hydroxide solubility, Alcohol-Benzene etc., for holocellulose, Alpha, Gamma & Beta Celluloses, pentosans, Klason lignin, and ash contents The results are recorded in Table No. I.

ii) Pulping :

Separate pulping of representative samples of chips of whole culms, nodal and internodal portions were carried out by sulphate pulping process under identical conditions, as cooking chemicals

Table—I

Proximate chemical analysis bamboo whole culm internodes and nodes

Sr. No.	Sample Particulars	1 Bamboo whole culm	2 Internodes	3 Nodes
1	Cold water solubility, %	2.9	3.0	3.9
2	Hot water solubility, %	4.3	4 3	4.9
3	1.0% NaOH solubility %	24.1	23.3	24.9
4	Alcohol-Benzene solubility, %	2.4	2.0	2 8
5	Holocellulose*, %	71.4	72.8	69.5
6	Alpha-cellulose, %	45.1	46.9	42.0
7	Beta-cellulose, %	8.2	5.7	9.0
8	Gamma-cellulose, %	11.6	15.3	13.6
9	Pentosans, %	19 3	18.9	20.6
10	Klason lignin, %	26.8	26.2	27.7
11	Ash, %	2.6	2.1	3.1

*Hllocellulose was determined by 5 treatments of sodium chlorite and is uncorrected for ash and residual lignin.

i. e., 13.5% as Na_2O on chips 'H' factors etc. To get pulp of Kappa No. 26 ± 1 of the nodal portion of chips also chemical charge was increased from 13.5% to 14.6% (as Na_2O) on O.D. chips. The results of pulping are recorded in Table No. II.

Table—II

Pulping of nodes, internodes and whole bamboo (Dowga)

Samples / Particulars	C.No. (1) Bamboo whole culm	C.No. (2) Internodes	C.No. (3) Nodes	C.No.(4) Nodes
+Active Alkali on chips as Na_2O, %	13.5	13.5	13.5	14.6
Bath ratio*	1:2.5	1:2.5	1:2.5	1:2.5
Cooking schedule:				
70°C to 120°C., mts.	45	45	45	45
At 120°C., mts	45	45	45	45
120°C to 165°C., mts.	45	45	45	45
At 165°C., mts.	45	45	45	45
'H' Factor	590	590	590	590
Black liquor				
pH	10 2	10.2	10.1	10.3
Total Dissolved solids, w/w basis, %	21.0	20.9	20.3	21.4
Residual Active Alkali as Na_2O, gpl	8.8	9.6	7.5	10.0
Unbleached pulp yield on chips, %	53.6	53.6	49.7	49 2
Rejects. %	nil	nil	0.3	nil
Kappa No.	25 8	24 8	30.1	26.8

+Whit liquor sulphidity—17.0%
*Water was used as dilutent

Bleaching :

The unbleached pulps of Kappa Nos. 26 ± 1 were bleached by CEHH sequence, to get bleached pulps of about 80% brightness (Elrepho). The results are recorded in table No. III.

iv) Bauer Mc Nett Classification of fibers :

This was done for bleached pulp samples using meshes 35, 50, 100 and 150. The results are recorded in Table No. IV.

v) Beating of the unbleached and bleached pulps:—

This was done in Laboratory Valley beater, to different°SR levels upto 50°. Standard handsheets of pulps of 60 ± 1 gsm were prepared at various freeness levels of the pulps on British Sheetmaking Machine. The strength properties of the standard handsheets were determined. The results of the unbleached standard handsheets and those of the bleached standard handsheets are recorded in Table No. V.

Discussion:

The nodal portion in the whole bamboo culm, was found to be 20%. The green volume density of internodal and nodal portion was found to be almost same.

i) The solubilities in cold water, hot water, 1.0% NaOH, and Alcohol–Benzene are comparatively higher in the case of nodal portion. Holocellulose and Alphacellulose contents are comparatively higher in the case of inter-

Table No. III

Bleaching of Pulps

	(1) Bamboo whole culm	(2) Internodes	(3) Nodes
Unbleached pulp Kappa No.	25.8	24.8	26.8
Chlorination Stage :			
Cl_2 added on pulp, %	7.00	7.00	7.00
Cl_2 consumed on pulp, %	5.80	6.00	5.84
Final pH	2.0	2.1	2.3
Alkali Extraction Stage :			
NaOH added on pulp, %	1.6	1.6	1.6
Final pH	9.6	9.7	9.7
Hypo Stage I :			
Cl_2 added on pulp, %	2.50	2.50	2.50
Cl_2 consumed on pulp, %	2.14	1.84	1.96
Final pH	7.1	7.3	7.2
Hypo Stage II :			
Cl_2 added on pulp, %	1.00	1.00	1.00
Cl_2 consumed on pulp, %	0.44	0.40	0.48
Final pH	7.6	7.6	7.6
Total Cl_2 added on pulp, %	10.50	10 50	10 50
Total Cl_2 consumed on pulp, %	8.38	8.24	8.28
Brightness (Elrepho), %	81.0	81.1	80.8
Shrinkage, %	11.3	11.0	12.0
Viscosity, Cps. (CED)	14.4	13.7	14.8

Constant Conditions :

	Temp., °C.	Retention time, Min.	Consistency %	% Sulfamic acid on Cl_2 added
C	28±1	60	3	—
E	55	60	5	—
H	45	60	5	2 0
H	45	90	5	5.0

Table No. IV

Bauer McNett Classification of Pulps

Mesh	Sieve opening, mm	Retained, % (1) Bambo whole culm	(2) Internodes	(3) Nodes
+35	0.500	57.2	66.0	30.3
−35+50	0.297	4.6	4.8	14.9
−50+100	0.149	2.6	2.7	17.3
−100+150	0.105	6.7	4.1	6.4
−150	—	28.9	22.4	31.1

nodal portion. Klason lignin and ash contents are comparatively higher in the case of nodal portion.

ii) The nodal portion consumes more active alkali. Moreover, to get the unbleached pulp of 26 ± 1 at the constant 'H' factor level, higher chemical charge was necessary, in the case of nodal portion. The unbleached pulp yield is lower by 4.4 percent in the case of nodal portion, (at the Kappa No. level of 26 ± 1) as compared to internodal portion, and the whole bamboo culm. With the identical cooking conditions, the yield of unbleached pulp, whole for bamboo culm, should have been lower, than that of the internodal portion. However, the values for both of these, are nearly the same. This may be due to higher Kappa Number of the unbleached pulp of the bamboo culm. Also, under identical cooking conditions, the nodal portion gave 0.3 percent rejects while the internodal portion and whole bamboo culm pulps were free from rejects This is very important from plant operation point of view, where ideal chip size as in laboratory is not available, and hence, the possibility of higher rejects or shives, because of the nodal portion.

iii) In bleaching, these three types of pulps, the chlorine consumption, and the trend

Table No. V (a)

Strength Characteristics of Standard Sheets of Unbleached and Bleached pulp of Bamboo whole culm

S. No.	1	2	3	4	1	2	3	4
Particulars	UNBLEACHED				BLEACHED			
Beating time, Min.	0	5	10	15	0	5	9	13
°SR	18	25	38	51	17	26	36	51
Drainage* time, Sec	6	14	34	62	6	14	31	51
Bulk, cc/g.	2.25	2.06	1.89	1.73	2.11	1.79	1.70	1.62
Breaking length, km	2.68	4.97	6.07	6.60	3.14	5 00	6.02	6.27
Stretch, %	1.9	2.6	3.0	3.3	1 8	2.6	3 2	3.3
T.E.A., J/m²	11	37	65	70	19	47	63	69
Double folds (MIT)	8	80	490	792	8	89	310	475
Tear factor	175	247	191	178	216	153	138	128
Burst factor	20.2	33.2	44.9	59.0	20.3	42.0	50.5	54.0
Porosity, Bendtsen, ml/min.	>3000	>3000	2140	580	>3000	2300	930	280

*Drainage time determined by Schopper Riegler

Table No. V (b)

Strength Characteristics of Standard Sheets of Unbleached and Bleached pulps of Bamboo Internodes

S. No.	1	2	3	4	1	2	3	4
Particulars	UNBLEACHED				BLEACHED			
Beating time Min.	0	5	0	15	0	5	10	14
°SR	16	22	34	48	16	24	37	47
Drainage* time. Sec.	5	10	23	49	5	11	31	50
Bulk, cc/g.	2.36	2.09	1.88	1.76	2.11	1.82	1.68	1.58
Breaking length km	3.10	4.64	5.96	6.66	3.12	5.20	5 45	6.04
Stretch, %	1.4	1.9	2.7	3 4	1.7	2.7	3.1	3.4
T.E A., J/m²	8	30	55	74	16	46	54	64
Double folds (MIT)	9	58	482	1095	11	91	400	475
Tear factor	185	251	210	200	162	145	137	113
Burst factor	18.9	35.6	48.8	56.6	20.7	39 2	49.0	53.8
Porosity, Bendtsen, ml/min.	>3000	>3000	1900	540	>3000	2600	515	200

*Drainage time determined by Schopper Riegler.

of bleaching, was observed to be similar.

iv) The Bauer Mc Nett classification of bleached pulp fibres, shows that the nodal portion, contains comparatively more short fiibres, than the internodal pulp, and pulp of whole culm.

v) Beating of the unbleached nodal pulp, was observed to be comparatively faster. Breaking length, stretch, tensile energy absorption (T.E.A.) were comparatively lower, In the case of unbleached and bleached nodal pulp, while double folds (MIT), tear factor and burst factor of the unbleached and bleached pulp of nodal portion were comparatively poor, as can be observed from Table V. The unbleached internodal pulp has comparatively higher double folds (MIT) and tear factor. Most of the strength properties of the unbleached and bleached pulps of inter nodal portion and whole bamboo culm are comparable.

Table No. V (c)
Strength Characteristics of Standard Sheets of Unbleached and Bleached pulp of Bamboo Nodes

S. No.	1	2	3	4	1	2	3	4
Particulars	UNBLEACHED				BLEACHED			
Beating time, Min.	0	5	9	13	0	5	10	14
°SR	17	26	38	50	17	23	36	48
Drainage* time, Secs.	6	14	29	56	5	12	26	50
Bulk, cc/g.	2.27	2.01	1.86	1.70	2.06	1.80	1.57	1 48
Breaking length, km	2.18	3.33	3.76	4 68	2.37	3.50	4.80	5.10
Stretch, %	1.1	1.6	2.0	2.1	1.5	2.2	2.6	3.2
T.E.A., J/m²	7	16	21	29	11	24	45	55
Double folds (MIT)	3	8	16	47	3	15	54	133
Tear factor	73.5	101.0	84.5	79.0	93.0	93.5	82.0	78.0
Burst factor	11.4	17.7	21.5	29.8	11.6	21.7	32 8	41.5
Porosity, Bendtsen, ml/min.	>3000	>3000	2540	630	>3000	3000	530	200

*Drainage time determined by Schopper Riegler.

Conclusion :

The results of the various experiments show the comparatively inferior nature of the pulp, produced from the nodal portion of bamboo. The nodal portion, along with its septum, is an integral part of the bamboo culm, and hence, likely to present difficulties, in separating it mechanically. In these days, when whole tree pulping and utilisation, is being advocated and also being practised in some places, the idea of separate pulping and processing of the nodal portion, does not seem to be attractive. The results of the experiments also show, that the pulp of the whole bamboo culm, and that of the internodes possess in general comparable strength properties. However, these studies reveal, the distinct features of the nodal portion of bamboo, and the resultant pulp namely, the comparative higher ash and Klason lignin contents, lower Alpha cellulose contents, comparatively higher requirement of chemicals for pulping, lower pulp yield, and tendency to produce more rejects on pulping, lower strength characteristics of the unbleached and bleached pulps due to very short fibre length.

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