Pulping Studies on Bamboos (Assam Green Bamboo and Old Bamboo) Hard Woods (Sal Scantling and Salai), Mixed Bamboos+Mixed Hard Woods (70:30) and Mills Chips.

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Assam Green Bamboo, Old Bamboo, Mixed Bamboo (A), Sal Scantling, Salai, Mixed hard wood (B), Mixed Bamboo (A) + Mixed hard woods (B) (70:30) and mill chips were evaluated for chips classification, bulk density, proximate chemical analysis, kraft pulping, bleaching and physical strength properties. It was observed that hard woods need higher alkali than Bamboo for producing bleachable grade pulp. It was also found that the pulps in higher yield could be produced by separate digestions and separate bleaching of Bamboos and mixed hard woods instead of mixed digestion of these two raw materials of heterogenous nature. Mixed hard woods used upto 30% in the mixed furnish has no detrimental effect on pulp quality and the physical strength properties.

India is on the threshhold of big developments for the enhancement of industries and the progress of the Country. Paper industry is one of the industry which is expanding rapidly to fulfil the demand of pulp, paper products but it is expected that the gap between demand and supply will increase with increase in population growth and advancement in civilization. In view of the shortage of paper and paper products as expected, India has to increase its installed capacity of paper and board industry to 42.5 lakhs tonnes per year by 2000 A.D. from the present 18.16 lakhs tonnes[1]. To meet this challenge 20 lakh A.D tonnes of Bamboo and 47 lakh tonnes of debarked wood will be required. In view of the shortage of Bamboo, Paper industry is constrained to use higher percentage of hard woods to meet the paper and paper products demand. This phenomenon of raw material shortage is a world wide global phenomena. The percentage of hard woods consumption has increased from 21% in 1970 to 25% in 1980 and it is expected that the percentage of hard woods will account 30% of the total wood material consumption for paper industry all-over the world[2].

Literature survey reveals that lot of work has been carried out on the pulping characteristics of Bamboo[3–8] mixed hard woods[9–26] and mixed pulping of Bamboo and mixed hardwoods[27–31]. It has been recommenneded that 30–35% of mixed hard woods[13,27] and even upto 50% can be used for manufacturing different grades of papers[11]. Mixed hard woods 30–35% used with Bamboo improves the quality of the pulp without detrimental effects on the pulping and bleaching characteristics.

At Orient Paper Mills, Amlai we are using 30–35% mixed hard woods (*Shorea Robusta* (Sal), *Boswellia Serrata* (Salai) *Terminalia Tomentosa* (Saza), *Diospyros Melanoxylon* (Tendu), *Adina Cordifolia* (Haldu) *Termiualia Chebula* (Harra) and *Garuja Pinnata* (Gunja) etc) along with Bamboo (mainly *Dendrocalmus Strictus*) for producing different grades of writing and printing papers. This project was initiated to carry out pulping of Bamboo and hard woods separately and to compare the findings of mixed pulping of Bamboos and mixed hard woods in the same proportion as in the mill chips to arrive at conclusive results. *Shorea Robusta* (Sal) and *Boswellia Serrata* (Salai) which comprises 80% of the total hard wood consumption in our mill were chosen for the mixed hard wood pulping whereas Assam Green Bamboo and old Bamboo were taken for mixed pulping of Bamboos.

EXPERIMENTAL :

Assam Green Bamboo, Old Bamboo, were chipped in Semner chipper whereas Sal Scantling and Salai

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were chipped in K.M.W. chipper. A representative sample of mill chips was also collected from the Silo Conveyer belt. Chips Classification of these samples was carried out in a william's chips classifer. The results of chips classification and bulk density are reported in table-1 Proximate chemical analysis of these samples except mill chips (—40, +60 mesh dust) was carried out and results are recorded in table—2.

Assam Green Bamboo, Old Bamboo, Mixed Bamboo (A), Sal Scantling, Salai, Mixed hard woods (B), Mixed Bamboos (A) +mixed hard woods (B) (70:30) and mill chips (—22, +10 m m) were digested in a 30 litre capacity electrically heated digester having indirect forced circulation arrangement with different alkali percentage (17.8% Sulphidity) under the identical cooking conditions and bath ratio was kept at 1:4. The cooking conditions and results are tabulated in table—3. The fibre classification of unbleached pulps was carried out in a Bauer Mcnett classifier. The fibres retained out in a Bauer Mcnett classifier. The fibres retained on different mesh is tabulated table—4

These unbleached pulps were bleached under C/E/H Sequence as per their chlorine demand for achieving a pulp brightness 78–80% P.V The bleaching conditions and results are given in table—5. These bleached pulps were evaluated for fibre classification and results are reported in table—6.

The different quality of bleached pulps were beaten at 45 SR in a laboratory valley beater. Standard sheets were prepared and tested as per Tappi Standards. The findings are recorded in table—7.

RESULTS & DISCUSSIONS :

The bulk density of various raw materials shows that Assam Green Bamboo has low bulk density (134.57 kg/m^3) due to long slievers, fine chips and higher moisture content (40 0%). Old Bamboo has bulk density 200 kg/m^3 whereas Sal Scantling and Salai chips have bulk densities 237 kg/m^3 and 167 54 kg/m^3 respectively. The low density of chips results in poor packing of the digester and lower pulp yield obtained/digester. Chips Classification as reported In table—1 shows that the percentage of over size chips is higher in Sal Scantling and Salai chips whereas —16 + 10 m m. and —10 m.m fraction was higher in Assam Green Bamboo and Old Bamboo as compared to mill chips.

The proximate chemical analysis of raw materials as given in table—2 shows that alcohal/Benzene solubility in Assam Green Bamboo is higher than Old Bamboo due to higher extractives present in green bamboo. The lignin content in Sal Scantling and Salai is higher than Assam Green bamboo and old bamboo which shows that these wood need drastic cooking conditions as compared to Bamboo. Higher pentosan content in Bamboos should help in beating of the pulps in a shorter time as compared to hard woods.

Assam Green Bamboo, Old Bamboo, and Mixed Bamboos (A) digested with 14%, 16% and 16% alkali for five hours (maximum temperature 164°C for 60 mts), results in unbleached pulp yield 47.94%, 41.24% and 45.0% respectively whereas the rejects percentage was 0.34%, 0.69% and 0.86% respectively. The permangnate No. of the pulps were 16.5, 18.7 and 18.0 respectively. The above findings shows that Assam Green Bamboo has higher pulp yield on laboratory scale due to uniform size of chips taken. The low pulp yield with green bamboo on plant scale is due to the long slivers and fine chips which results in poor packing of the digester. The permangnate No. of the pulps and black liquor analysis recorded in table—3 shows that the alkali requirement of Assam Green Bamboo is lower as compared to old and mixed bamboos.

Sal Scantling, Salai chips and mixed hard woods (B) digested with 18%, 18% and 19% alkali for five hours (maximum hold time 50mts at 164°C) results in unbleached pulp yield 43.29%, 43.56%, and 44.20% respectively whereas the rejects percentage was 1.33%, 0.99% and 0.60% respectively. The permangnate No. of the pulps were 22.5, 18.4 and 20 6 respectively. The black liquor analysis and permangnate No. of the pulps recorded in table—3 shows that Sal Scantling and mixed hard woods require drastic cooking conditions than Salai, Assam Green Bamboo, Old Bamboo and mixed Bamboos.

Mixed Bamboos (A) + Mixed hard woods (B) (70:30) and Mill chips were also digested with 17% and 18% alkali respectively for five hours (maximum hold time 60 mts at 164°C) results in unbleached pulp yield 42.2% and 37.23% respectively whereas the rejects percentage was 3.0% and 8.60% respectively. The permangnate No. of the pulps were 18.6 and 18.5 respectively. It was observed that the pulp yield in the digestion of Bamboos (A)+ mixed hard woods (B) (70:30) was lower (42 2%) than mixed hard woods 44.2%) and mixed Bamboos (A) (45.0%). The lower

TABLE—1 Chips Classification and Bulk density of Assam Green Bamboo, Old Bamboo, Sal Scantling, Salai chips and Mill chips.

S. No.	Particulars Screen Size	Assam green Bamboo	Old Bamboo	Sal Scantling	Salai	Mill Chips
1.	+29 mm	8.303	4.828	16.158	24.005	16.26
2.	−29+22mm	6.524	4.024	13.898	19.760	14.25
3.	−22+16mm	19.335	17.706	27.570	27.453	22.72
4.	−16+10mm	43.534	41.289	28.926	19.628	28.29
5.	−10+5 mm	14.709	17.303	10.286	5.702	14.03
6.	− 5 mm	7.591	7.847	4.425	3 448	4.45
7.	Acceptable chips (%)	69.397	70.022	69.131	66.845	65.26
8.	Rejects (%)	30.603	29.978	30.869	33.155	34.74
9.	Moisture in cnips(%)	45.00	15.00	14.00	42 90	51.3
10.	Bulk density (kg/m³)	134.57	199.69	237.03	167.54	205.4

TABLE—2 Proximate chemical analysis of Assam Green Bamboo, Sal Scantling and Salai dust.

S. No	Particulars	Assam Green Bamboo	Old Bamboo	Shorea Robusta (Sal)	Boswellia Serrata (Salai)
1.	Cold water solubility (%)	3.92	3.52	2 15	6.30
2.	Hot water solubility (%)	6.96	5.52	5.12	8.90
3.	1% NaOH solubility %)	22.78	22.28	15.30	15.50
4.	Alchohol/Benzene solubility (%)	4.88	2.82	1.94	4.30
5.	Hollo Cellulose (%)	73.62	72 04	60.10	63.85
6.	Pentosan (%)	18.18	17.20	14.30	13 0
7.	Lignin (%)	23.50	25 84	28.80	27.30
8.	Ash (%)	2.37	2.10	0.92	1.00

* Lignin reported is ash corrected.

TABLE—3 Kraft Pulping of Assam Green Bamboo, Old Bamboo, Mixed Bamboos (A), Sal Scantling Salai, Mixed Hard woods (B), Mixed Bamboo (A)+Mixed Hard woods (B) (70:30) and Mill chips.

S.No.	Particulars	Assam Green Bamboo	Old Bamboo (A)	Mixed Bamboos. (A)	Sal Scantling (B)	Salai (B)	Mixed hard woods (B)	Mixed Bamboo (A) + Mixed hard woods (B) (70:30)	Mill chips
1.	Chemical applied (%) as Na_2O	14.2	16.2	16.0	18.0	18.0	19.0	17.0	18.0
2.	Sulphidity (%)	17.2	17.2	17.2	17.2	17 2	17.2	17.2	17.2
3.	Bath ratio	1:4	1:4	1:4	1:4	1:4	1:4	1:4	1:4
4.	Cooking schedule (mts)								
	(a)Upto 135°C	120	120	120	120	120	120	120	120
	(b)At 135°C	60	60	60	60	60	60	60	60
	(c) From 135-164°C	60	60	60	60	60	60	60	60
	(d) At 164°C	60	60	60	60	60	60	60	60
	(e) Total time (hrs)	5.0	5.0	5.0	5.0	5.0	5 0	5.0	5.0
5.	H-factor	845	845	845	845	845	845	845	845
6,	Permangnate No	16.5	18.7	18.0	22.5	18.4	20.6	18.6	18.5
7.	Rejects free yield (%) (on O.D. basis)	47.94	41.24	45.0	43.29	43.56	44.20	42.2	37.23
8.	Rejects (%) (on O.D. basis)	0.34	0.69	0.86	1.33	0.99	0.60	3.0	8 60
9.	Black Liquor Analysis								
	(a) °TW at 60°C	17.0	18.0	16.5	20.5	19.0	17.5	16.0	19.5
	(b) R.A.A (g/L) as Na_2O	15.5	18.6	17.05	21.7	18.6	17 82	17.05	19.15

TABLE–4

Fibre Classification of Assam Green Bamboo, Old Bomboo, Mixed Bamboos (A) Sal Scantling, Salai, Mlxed hard woods (B), Mixed Bomboos (A)+Mixed hard woods (B) (70:30), Mill chips unbleached pulps.

S. No.	Mesh size	Assam Green Bamboo retention (%)	Old Bamboo retention (%)	Mixed Bamboo (A) retention (%)	Sal Scantling retention (%)	Salai retention(%)	Mixed hard woods (B) retention (%)	Mixed Bambos (A) + Mixed hard woods (B) (70:30) retention (%)	Mill chips pulp retention (%)
1.	+20	57.38	51.68	53.14	11.63	9.96	10.98	44.35	39.03
2.	—20+40	4.73	5.20	5.10	13.04	8.70	12.20	5,85	6.56
3.	—40+70	15.30	17.86	16.82	50.92	66.52	54.34	26.64	29.27
4.	—70 +100	4.13	4.42	4.94	6.72	6.90	5.84	7.54	6.09
5.	—100,+140	2.29	2.49	3.54	2.77	1.81	3.92	3.04	2.35
6.	—140	16 17	18.35	16.46	14 92	6.07	12.72	12.58	16.70
7.	Total	100.00	100.00	100,00	100.00	100.00	100.00	100.00	100.00

TABLE–5

Bleaching of Assam Green Bamboo, Old Bamboo, Mixed Bamboo (A), Sal Scantling Salai, Mixed Hard woods (B), Mixed Bamboo (A)+Mixed hard woods (B) (70:30) and mill chips pulps under C/E/H Sequence.

S. No.	Particulars	Assam Green / Bamboo	Old Bamboo / (A)	Mixed Bamboo (A)	Sal Scant- / ling	Salai / (B)	Mixed Hard woods (B)	Mixed Bam- boo + Mixed hard woods (B) (70:30)	Mili chips pulp
1.	2.	3.	4.	5.	6.	7.	8.	9.	10,
1.	Permangnate No. of pulps	16.5	18.7	18.0	22.5	18.4	20.6	18.6	18.5
2.	**Chlorination Stage**								
	(i) Chlorine applied (%) (on O.D. Pulp)	5.50	7.50	7.50	9.50	7.50	9.00	8.00	7.5
	(ii) Chlorine consumed (%)	5.40	7.36	7.43	9.20	7.38	8.86	7.70	7.28
	(iii) End pH	2.0	1.8	1.8	2.4	2.0	2.1	1.9	2 0
2.	**Alkali Extraction Stage**								
	(i) Alkali applied (%)	2.5	2.5	2.5	2.5	2.5	2.5	2 5	2 5
	(ii) End pH	10.6	10.5	10.5	10.4	10.4	10.4	10.5	10.5
4.	**Hypochlorite Stage**								
	(i) Hypochloriate applied (%)	3.0	3.5	3.5	4 5	3.5	4 0	3.5	3.5
	(ii) Buffer added (%)	0.8	0.8	1.1	0.9	0.6	0.7	0.6	0.6
	(iii) Hypochlorite consumed%	2.80	3.30	3.08	4.07	2.25	3.36	2 90	2.70
	Constant conditions :—								
	(a) Sequence	C	E	H					
	(b) Consistency (%)	3 0	5.0	5.0					
	(c) Temperature°C	Room	50	40					
	(d) Retention time (mts)	60	60	120					
5.	**Final results**								
	(i) Total chlorine applied (%)	8.50	11.0	11.0	14.0	11.0	13.0	11.5	11.0
	(ii) Total chlorine consumed %)	8.20	10.66	10.51	13.27	8.63	12.22	10 60	9 98
	(iii) Brightness of pulp (%)P.V.	79.0	78.0	78.0	79.5	79.5	79 5	79 5	79.5
	(iv) Copper No.	1.08	1.20	1.15	1.46	1.42	1.46	1 40	1.33
	(v) Viscosity (0.05%, CED) CpS	12.44	10 88	11.40	7.44	7.96	7.46	8.37	8.88
	(vi) Shrinkage of pulp (%) (on O.D. raw material)	8.60	10.44	10.0	12.88	10.99	11.5	12.0	10.66
	(vii) Bleached pulp yield (%) on O.D. raw material	43.71	36.93	40.5	37.71	38.81	39.12	37.1	35.14

TABLE–9

Fibre Classification of Assam Green Bamboo, Old Bamboo, Mixed Bamboo (A), Sal Scantling, Salai, Mixed hard woods 'B', Mixed Bamboos (A)+Mixed hard woods (B) (70:30) and Mill chips bleached chips.

S.No.	Mesh size	Assam Green Bamboo retention (%)	Old Bamboo retention (%)	Mixed Bamboo (A) retention (%)	Sal Scantling retention (%)	Salai retention (%)	Mixed Hard woods (B) retention (%)	Mixed Bamboo (A) + Mixed Hard woods (B) (70:30) retention (%)	Mill chips retention (%)
1.	+20	56.72	48.98	52.20	11.22	6.87	9.05	42.20	31.81
2.	+20, -40	5.21	4.97	5.38	11.91	5.24	12.24	7.25	6.93
3.	-40, +70	14.84	23.95	14 20	53.66	62.16	53.54	30.54	34.50
4.	-70, +100	4.46	5.73	3.45	7.79	16 71	6.14	5 20	8.98
5.	-100, +140	1.82	1.31	3.45	2 32	2 4	6 05	2 24	2.13
6.	-140	16.95	15.86	21.32	13.10	6 88	12 98	12 57	15.65
7.	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE–7

Physical strength properties of Assam Green Bamboo, Old Bamboo, Mixed Bamboo (A), Sal Scantling, Salai, Mixed hard woods (B), Mixed Bamboos (A)+Mixed hard woods (B) (70:30) and Mill chips bleached pulps.

S.No.	Particulars	Assam Green Bamboo	Old Bamboo	Mixed Bamboo (A)	Sal Scantling	Salai	Mixed hard woods (B)	Mixed Bamboo (A) + Mixed hard woods(B)(70:30)	Mill chips pulp
1.	Initial freeness° SR	15	17	16	16	19	16	17	16
2.	Final freeness° SR	45	45	45	45	45	45	45	45
3.	Beating time (mts)	35	31	32	49	31	40	34	38
4.	Bulk (cc/g)	1.35	1.32	1.32	1.42	1.37	1 40	1.42	1.38
5.	Tensile Index (N.m/g)	73.18	65.83	71.32	65.98	63.92	65.88	69.17	64.14
6.	Burst Index ($K.Pa.m^2/g$)	6.45	4.45	5.24	4.47	4.54	4.53	5.26	5.04
7.	Tear Index ($mN.m^2/g$)	6.57	6.56	6.30	4.36	3.56	3.99	5.50	5 94
8.	Double fold	540	550	650	480	166	240	370	280

pulp yield in the mixed cooking may be attributed due to the heterogenous nature of mixed hard woods and Bamboos. Laboratory digestion also confirm this view point that the pulp yield in the mixed digestion (mill chips) was still over (37.23%) than Bamboos (A) + Mixed hard woods (B) 70:30) as well as Bamboos (A) and Mixed hard woods (B). The higher rejects in the mill chips is due to presence of over size chips. In the digestion of the mill chips the lower pulp yield encountered may be due to the reason that Bamboo chips are over cooked and hard woods produced higher rejects as both the raw materials have different chemical requirement.

Fibre classification of unbleached pulps shows that Bamboo fibres have higher retention (%) on + 20 mesh whereas hard woods have maximum retention (%) on-40, + 70 mesh. Mixed Bamboo (A) + mixed hard woods (B) (70:30) has also higher fibre retention on + 20 mesh as expected. Although in the mill chips

the fibre retention percentage on + 20 mesh is higher but it is lower than Bamboo (A) + mixed hard woods (B) (70:30), which confirm that mill chips contain higher hard wood percentage.

Assam Green Bamboo, old Bamboo, Mixed Bamboos (A), Sal Scantling, Salai, Mixed hard woods (B), Mixed Bamboo (A), + Mixed hard wood (B) (70:30), and mill chips unbleached pulps were bleached under C/E/H Sequence as per the chlorine demand for a pulp brightness of 78-80% P.V.A perusal of table—5 shows that the chlorine consumption of Assam Green Bamboo, Old Bamboo and Mixed Bamboos (A) was higher than Sal Scantling, Salai and Mixed hard woods (B) as expected according to their permangnate No. and literature surveyed.[31] The pulp shrinkage during bleaching of Assam Green Bamboo, Old Bamboo and Mixed Bamboo (A) were 8.60%, 10.44%, 10.0%, respectively; viscosity 12.44, 10.88 and 11.40 cps respectively; Copper No. 1.08, 1.20 and 1.15 respectively whereas in Sal Scantling, Salai, and Mixed hard woods (B) the pulp shrinkage were 12.88%,10.99% and 11.5% respectively; viscosity 7.44, 7.96 and 7.46 respectively; and Copper No. 1.46, 1.42. and 1 46 respectively. It can be concluded that the pulp shrinkage and Copper No. in Bamboo pulps in bleaching was lower as compared to hard wood pulps whereas reverse trend was observed in viscosity. Mixed Bamboo (A) + Mixed hard woods (B) (70:30) and mill chips pulps bleached under C/E/H Sequence shows that the pulp shrinkage were 12.0% and 10.66% respectively; viscosity 8.37 and 8.88 cps respectively; Copper No. 1.40 and 1.33 respectively. The pulp shrinkage and Copper No. of Mixed Bamboo (A) + Mixed hard woods (B) (70:30) was higher than Bamboo pulps and comparable with hard woods pulps and reverse trend was observed with the pulps viscosity. It can also be concluded from table–5 that the bleached pulp yield of mill chips was lower than Mixed Bamboos (A), Mixed hard woods (B) and Mixed Bamboos (A) + Mixed, hard woods (B) (70:30) by about 5.36%, 3.98% and 1.96% respectively.

The fibre classification studies of different bleached pulps reported in table 6 shows that the percentage of fibre retention + 20 mesh has decreased as compared to unbleached pulps.

The physical strength properties recorded in table-7 indicates that the tensile Index and burst Index of Assam Green bamboo was higher than old Bamboo and Mixed Bamboos (A). The superior strength properties of Green Bamboo has also been reported earlier.[8] The physical strength properties of Hard wood pulps were inferior to Bamboo pulps viz the tensile index and Tear index. Hard wood pulps have higher bulk as compared to Bamboo pulps. The physical strength properties of Mixed Bamboos (A) + Mixed hard woods (B) (70:30) pulps were inferior to Bamboo pulps but higher than hard wood pulps and Mill chips pulp.

Conclusion :

It can be concluded that hard woods should be given 2.0-3.0% higher alkali than Bamboo for producing bleachable grade of pulp. The severe pulping conditions required for hard woods is due to higher lignin content, high bulk density and dense structure as compared to Bamboo. Individual pulping of different Bamboos and different hard woods is not feasible on plant scale but if mixed Bamboos and mixed hard woods are provided separate street for pulping and bleaching, improvement in pulp yield may be observed as compared to Bamboo+Mixed hard woods (70:30) pulping and bleaching. In case we have to continue mixed digestion of Bamboos+mixed hard woods due to economical reasons for modification in the existing plant and machinery use of higher alkali will be benificial in reducing rejects percentage and improvement in pulp yield. It has also been noticed that upto 30% mixed hard woods admixed with Bamboo in pulping and bleaching has no detrimental effect on the pulp quality and the physical strength properties Uniform size of chips should be fed to the digester for obtaining higher puld yield, reduction in rejects percentage and improvement in physical strength properties as evident from the pulping and bleaching studies of mill chips pulp.

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REFERENCES :

1. Rao, N.J, *IPPTA Conventional Issue*, 1983
2. Kyrlund, B. and Lintu. L., *IPPTA Conventional Issue*, 1983.

3. Sadawarte, N.S. and Prasad, A. K. *IPPTA*, Vol XIII, No. 3, 1976.

4. Maheshwari, S, Jaspal, N.S., and Bhargava, R. L. *IPPTA Vol XII*, No 4, 1976.

5. Jauhari, M. B. Jaspal, N.S, and Bhargava, R.L., *IPPTA, Vol* VIII, No. 2, 1971.

6. Sadawarte, N.S. and Prasad A. K, *IPPTA Sovenir*, 1975.

7. Pant, etal *UNDP/FAO-GOI, PROJECT-IN/73/012, Report No. 15*, February 1980

8. Jauhari, M.B. etal *IPPTA, Vol VIII*, No. 3, 1971

9. Misra, N.D., Gupta, L. G. and Ashwathnarayan, K; *IPPTA Vol VIII*, No. 4, 1971

10. Bhatt R.K, etal *IPPTA, Vol VII*, No. 3, 1970.

11. Krishnamachari, K.S. Rangan, S.C.' Ravindranathan, N, and Reddy; D.V, *IPPTA, Vol IX*, No. 3, 1972.

12. Bhargava, R.P, *IPPTA*, Sept. 1968.

13. Bhargava, K. S. *IPPTA*, Sept 1968.

14. Erland P, Victor, S, and Chandrashakharan, C; *IPPTA* 1969

15. Misra, N. D., Venkateshwara Rao, A; I*PPTA*, March 1969.

16. Singh, M.M., and Bhola P. P , *IPPTA Vol XIV*, No. 2, 1977.

17. Jauhari, M. B. and Bhargava, R.L., *IPPTA XIII*, No. 4, 1976.

18. Mittal, K.C; Naithani, N.K, and Biswas B; *IPPTA*, Vol XV No. 3, 1978.

19. Mittal, K.C; Naithani, N K. Subhashchandra and Tapadar, D.C; *IPPTA*, Vol X, No. 3,, 1973.

20. Mohan Rao, N. R etal *IPPTA, Vol XIX*, No. 3, 1982.

21. Phillips, F.H., Logan, A F. and Balodis V; *TAPPI Vol* 62, No. 3, 1979.

22. Kopanidis. J; *Tappi, Vol 60*, No.2, 1977.

23 Scurfield, G; *Tappi, Vol 59*, No. 7, 1976.

24. Hernadi, S; and Lengyel P; *Tappi, Vol 59*, No. 10, 1976.

25. Jett, J. B; and Jobel, B. J; *Tappi, Vol 58*, No. 1, 1975.

26. Barker. R. G; *Tappi, Vol 57*, No. 8, 1974.

27. Singh, T.M; Panda, G.S; and Hangal, P.S ; *IPPTA Vol X*, No. 3, 1973.

28. Sadawarte, N. S; Prasad A.K; and Kabildas, M.G. *IPPTA, Vol XVIII*, No. 1, 1981.

29. Seth V. K; *IPPTA, Vol VIII*. No. 2, 1971.

30. Banerjee, A. K; *IPPTA, Vol XIV*, No. 4, 1977.

31. Rai, P.A; and Jaspal, N.S; *IPPTA, Vol XVII*, No.4 1976.