Wet Cleaning of Straws For Improving Pulp Quality

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ABSTRACT

Wheat straw and rice straw were washed with water and 1.00% sodium hydroxide prior to pulping with an aim to assess the influence of washing on pulping, bleaching and paper making characteristics, Under the identical conditions of pulping (11% alkali charge), unbleached pulp yield was 50.66% and 44.96 with kappa number was 31± 0.97 and bleached pulp yield was 47.37% and 42.04% for alkali and water washed wheat straw as against 42.04% for alkali and water washed wheat straw as against 42.00% and 39.29%, respectively, for respective control sample. Similarly, rice straw (7% alkali charge yielded 48.30% and 43.80% unbleached pulp with kappa number was 23.3 ± 1.3) and bleached pulp yield was 46.27% and 41.59% for alkali and water washed sample as against 37.20% and 35.49%, respectively, for respective control samples.

Bleached pulps from both the straws, produced under identical conditions, exhibited 20 to 25% improvement in bonding properties (except comparable tensile index for rice straw), as compared to control sample. Pulps produced, even at 1% lower alkali charge for water and 1% and 2% lower alkali charge for alkali washed wheat straw sample, yielded pulps with comparable, burst index, 3.89 ± 0.13, tensile index 64.84, ± 3.5 and tear index 4.43 ± 0.07. Rice straw pulp produced using 1% less alkali charge for alkali washed sample exhibited comparable tensile index 48.73 ± 0.75 to that of control sample. Pulp produced from rice straw, using 1% and 2% less alkali charge in the case of water washed and alkali washed sample, respectively, exhibited comparable burst and tear index and marginally poor tensile index as compared to control sample. Brightness gain was 13.5 ± 1.5 and 5.5 ± point ISO for wheat and rice straw pulps, respectively, as compared to pulp produced from control sample.

On the basis of data generated on unbleached/bleached pulp yield, an attempt has been made to work out the economic feasibility of water and alkali washing of wheat and rice straws. Due consideration has been paid to weight loss during washing of straws. However, Operational inputs could not be included due to non-availability of adequate data. It was concluded that to produce same amount of pulp, less amount of

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washed straws and pulping chemical would be required. It is also anticipated that washing would improve the effective pulp mill capacity and paper machine runnability, consequently, improve the quantity and quality of pulps from straws.

INTRODUCTION

Cereal straws, in general, contain high amount of inherent silica, which is present in the epithelial cells of plants, dirt particles and parenchymatous cells mainly from leaf sheaths. The parenchymatous cells are short and weak easily attached by alkali than that of clums, consuming considerable amount of alkali in the early stage of pulping leaving comparatively less chemicals for subsequent delignification and yield little pulp which in the final pulp act as a filler. The filler materials clogup with paper machine wire, sticks to press roll fill up the felt and adversely effect the machine speed, consequently, decreased the production and strength properties of end product. Further, the pulp from leaf sheath is much difficult to bleach than clum fibres (Fouad, 1962, Muller, 1962).

Silica present (inherent or adhered) in raw materials dissolve in alkaline solution and form sodium silicate. In the presence of calcium salts, it tend to form calcium silicate which form scales in the liquor heat exchanger of indirectly heated digester, increase the steam consumption of the digestion system and erode various process equipments. The abrasive nature of silica is critical in refining of high yield pulps. However, the worst affected section is the multiple effect evaperators and caustisizing section of chemical recovery system (Panda, 1990).

The presence of these components in the raw materials leads to additional pulping chemical consumption besides dead load in digester and increased silica in pulp and/or black liquor. Thus, the partial removal of the silica (inherent or adhered) and parenchymatous cell from straws would be advantageous to improve quality and quality of the pulp.

EXPERIMENTAL

Washing of straws

About 1.0 kg of straw was loaded in laboratory hydrapulper and water was added to it to maintain in straw to water ratio 1:15. In another case 1.00% NaOH (on o.d. straw basis) was also added. The material was kept under stirring for about 10 minutes. Straw was picked up manually and air dried. These straw samples were designated as **water washed (W) and alkali washed (A) straw.**

Proximate chemical analysis of straw

Extractive free straw meal (40-60 mesh) was subjected to 1% NaOH solubility, klason lignin and ash content determination by adopting TAPPI standard methods, T-207-OS-76, T-204-OS-76 and T-15-OS-58, respectively. Holocellulose was determined by the method of Wise et. al. (1946).

Pulping of straws

Pulping experiments were carried out using different pulping chemical dosages in air bath pulping unit consisting of six bombs. In each case, total cooking time was 3.0 hr and 10 minutes including half an hour to raise the temperature from room temperature to 100^{0}C. From 100^{0}C to 160^{0}C temperature was raised at the rate of 10^{0}C rise in 15 minutes.

The maximum temperature, 165^{0}C was raised from 160^{0}C in 10 minutes. Cooking at maximum temperature was carried out for an hour. The cooking cycle corresponds to 810 H factor. Straw to liquor ratio was 1:5 in each case. The cooked material was washed with hot water and screened over laboratory screen using flat screen plate having 0.20 mm slots. Total and screened pulp yield and kappa number were determined in each case.

Bleaching of straw

Unbleached pulps, thus obtained, were bleached in two stages using calcium hypochlorite. 40^{0}C temperature, 8% consistency and 9.5 $\pm$ 0.5 pH was maintained in each stage. Bleaching was carried out for one hour in each stage. Pulps were washed with fresh water after each stage.

Beating, sheet making and strength properties of hand sheets

The bleached pulps were beaten in PFI mill at different revolutions. Standards sheets of about 65 $\pm$ 2 gsm were made in a standard British sheet making machine. The sheets were pressed, air dried, conditioned at 27 $\pm$ 1 ^{0}C and 65 $\pm$ 2% relative humidity and tested for various physical strength properties. Properties were interpolated at freeness 250 ml CSF.

Table-1

Proximate analysis of wheat and rice straw

Particulars	Wheat straw			Rice straw		
	Control	Water washed	Alkali washed	Control	Water washed	Alkali washed
Weight loss, %	-	8.00	10.00	-	12.00	15.00
Ash, %	6.26	4.45	3.96	14.69	10.32	8.84
Klason lignin*, %	15.23	16.75	15.50	10.66	11.51	10.88
Holocellulose, %	68.67	74.05	75.00	56.80	64.73	66.72

Percentage on o.d. straw.* corrected for ash.

RESULTS AND DISCUSSION

Water and alkali washed wheat straw suffered 8 percent and 10 percent weight loss. Silica content was decreased from 6.26 percent for control sample to 4.45 and 3.96 percent for water and alkali washed straw, respectively. Rice straw suffered 12 and 15 percent weight loss on water and alkali washing in laboratory hydrapulper. Same practice can be used in mill scale washing of straws at mill scale requiring no additional equipment. Effluent generated could partially be used in subsequent washing after

Table-2

Pulping and bleaching condition pulp yield and properties of wheat straw pulps

Particulars	Control	Water washed		Alkali washed		
		W_1	W_2	A_1	A_2	A_3
Alkali charge,* (%) as NaOH	11	11	10	11	10	09
Total pulp yield, * (%)	45.43	48.78	53.05	52.66	56.37	58.76
Screened pulp yield (%)	42.00	44.96 (41.36)	47.60 (43.79)	50.66 (44.58)	52.82 (46.48)	54.26 (47.75)
Kappa number	30.85	32.78	36.32	32.07	34.76	46.32
Total chlorine applied, ** (%)	7.75	8.25	9.20	8.00	8.75	11.75
Chlorine applied in Ist stage hypo., ** (%)	5.50	5.75	6.40	5.50	6.10	8.25
Chlorine applied in IInd stage hypo., ** (%)	2.25	2.50	2.80	2.50	2.65	3.50
Bleached pulp yield, ** (%)	93.55	93.50	93.10	93.50	93.40	92.88
Bleached pulp yield, * (%)	39.29	42.04	44.32	47.37	49.33	50.40
Bleached pulp brightness, ISO (%)	58.9	74.6	72.6	75.1	74.6	73.6
Burst index $kPam^2/g$	3.77	4.70	3.74	4.68	4.02	3.81
Tensile index Nm/g	63.22	75.47	68.34	75.34	63.80	61.34
Tear index mNm^2/g	4.50	4.42	4.39	4.38	4.37	4.45

Figures given in parenthesis are based on original straw
* Based on o.d. raw material
** Based on unbleached pulp.
Strength properties at freeness 250 CSF

Screened pulp yield of water and alkali washed wheat straw

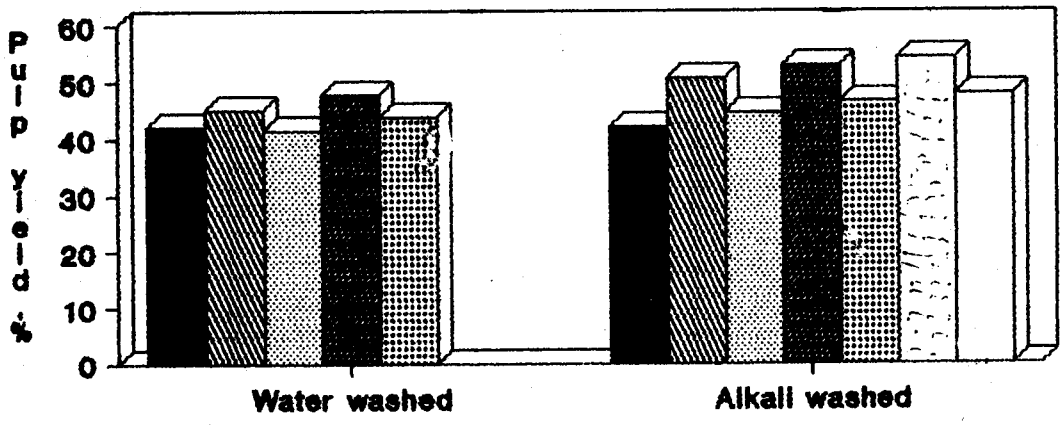
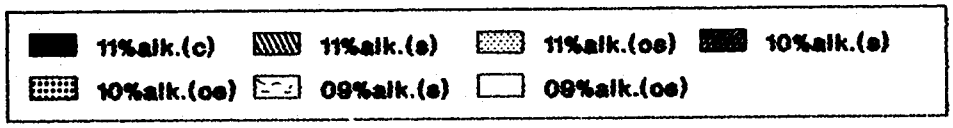


Fig - 1



c, s and os stands for yield of control, sample and yield based on washed and straw, respectively.

Screened pulp yield of water and alkali washed rice straw

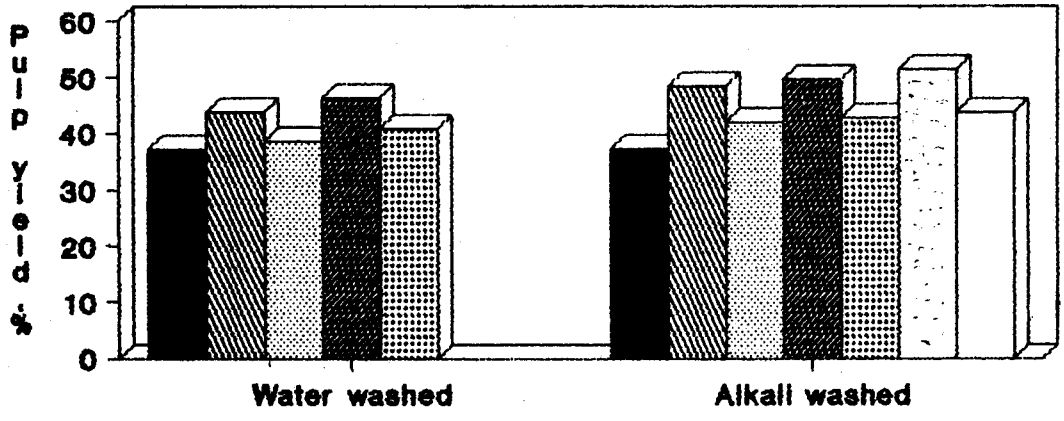
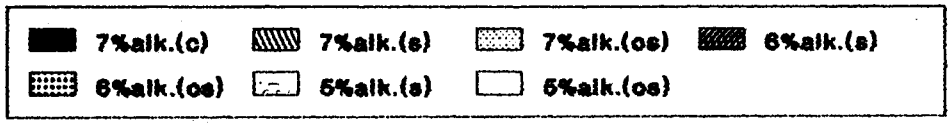


Fig - 2



c, s and os stands for yield of control, sample and yield based on washed and straw, respectively.

Table-3

Pulping and bleaching condition pulp yield and properties of rice straw pulps

Particulars	Control	Water washed		Alkali washed		
		W_1	W_2	A_1	A_2	A_3
Alkali charge,* (%) as NaOH	7	7	6	7	6	5
Total pulp yield, * (%)	40.44	46.50	50.28	50.46	52.48	55.09
Screened pulp yield (%)	37.20	43.80 (38.54)	46.28 (40.73)	48.30 (41.05)	49.48 (42.60)	51.31 (43.61)
Kappa number	21.98	24.56	32.46	22.86	28.60	31.68
Total chlorine applied, ** (%)	5.50	6.25	8.25	5.50	7.25	8.00
Chlorine applied in Ist stage hypo., ** (%)	3.50	4.25	5.75	3.50	5.00	5.50
Chlorine applied in IInd stage hypo., ** (%)	2.00	2.00	2.50	2.00	2.25	2.50
Bleached pulp yield, ** (%)	95.40	94.95	94.00	95.80	94.63	94.25
Bleached pulp yield, * (%)	35.49	41.59	43.50	46.27	46.82	48.34
Bleached pulp brightness, ISO (%)	62.9	65.5	63.0	70.5	61.8	57.7
Burst index $kPam^2/g$	2.63	3.06	2.62	3.58	2.72	2.48
Tensile index Nm/g	49.48	49.71	45.98	56.40	47.98	44.49
Tear index mNm^2/g	4.54	4.59	5.19	4.46	4.47	4.69

Figures given in parenthesis are based on original straw
* Based on o.d. raw material
** Based on unbleached pulp.
Strength properties at freeness 250 CSF

sedimentation/ screening out the organic and inorganic matter. Sedimented/screened material could be used land filling or even for energy generation. Silica content decreased from 14.69 percent for control to 10.32 and 8.84 percent for water and alkali washed straw. Klason lignin was increased marginally on washing, while the increase in holocellulose was appreciably high, about 7 to 10% **(Table-1).** Increase in klason lignin and hollocellulose may be attributed to partial removal of inherent and adhered silica and other inorganics, parenchymatus cells, water and alkali soluble fractions (extractives) during washing. These were contributing to the weight of the straws but inorganics are not contributing to cell wall components while parenchymatous cells are easily attacted by chemicals. subsequently leading to given rise to straw containing higher amount cell wall components i.e. lignin and hollocellulose due to removal of ash and extractives.

Under the indentical conditions of pulping at 11% alkali charge, delignification was almost comparable (kappa number 31.82 $\pm$ 0.97) **(Table-2)** for control and, water and alkali washed straw samples. However, slightly higher kappa number for washed straw samples may be partially, attributer to slightly higher klason lignin in washed straw samples and patially to partial removal of easily soluble (low molecular weight) lignin, generally present in grasses and agricultural residue, leaving higher proportion of comparatively more alkali resistant high molecular weight lignin in washed straw sample (particularly in alkali washed straws sample).

Screened unbleached pulp yield was 50.66% and 44.96% and bleached pulp yield was 47.37% and 42.04% for alkali and water washed wheat straw as against 42.00% and 39.29%, respectively **(Table-2, figure-1).** Bleached pulps (H/H bleaching sequence) exhibited nearly 25% higher burst index and 20% higher tensile index as compared to control sample. Even at 1% lower alkali charge for water and 1% and 2% lower alkali charge for alkali washed sample, properties were comparable, burst index, 3.89 $\pm$ 0.13, tensile index 64.84, $\pm$ 3.5 and tear index 4.43 $\pm$ 0.07. Brightness gain was 13.5 $\pm$ 1.5 point ISO for all

Table-4

Approximate estimated economics of unbleached and bleached wheat straw pulps

Particulars		Water washed		Alkali washed		
	Control	W_1	W_2	A_1	A_2	A_3
Alkali (%)	11.00	11.00	10.00	11.00	10.00	09.00
pulp yield, * (%)	42.00	44.96	47.60	50.60	52.82	54.26
Straw/tubp, kg.	2381	2224 (2417)	2100 (2282)	1974 (2243)	1893 (2151)	1843 (2094)
Cost/tubp, Rs.	2381	2274	2100	1974	1893	1893
Alkali/tubp, kg.	262	245	210	217	189	166
Alkali/tubp, kg. (during washing)	-	-	-	23	22	21
T. alkali/tubp, kg.	262	245	210	240	211	187
Cost of alkali/tubp, Rs.	2882	2695	2310	2640	2321	2057
Cost/tubp	5263	4969	4410	4614	4214	3950
Ubp/tbp	1.069	1.069	1.074	1.069	1.071	1.077
Cost of ubp/tbp, Rs.	5626	5312	4736	4936	4513	4254
Chlorine/tubp, kg.	83	88	99	86	94	105
Cost of Chlorine/tbp, Rs.	498	528	594	516	564	630
Cost/tbp, Rs.	6124	5840	5330	5448	5077	4884

* Based on o.d. straw. Figures in parenthesis based on original straw. **tubp and tub** stands for tonne unbleached and bleached pulp

Table-5

Estimated economics of unbleached and bleached rice straw pulps

Particulars		Water washed		Alkali washed		
	Control	W_1	W_2	A_1	A_2	A_3
Alkali (%)	7	7	6	7	6	5
pulp yield, * (%)	37.2	43.80	41.28	48.30	49.48	51.31
Straw/tubp, kg.	2688	2283 (2594)	2161 (2456)	2070 (2435)	2021 (2378)	1949 (2293)
Cost/tubp, Rs.	1613	1557	1474	1461	1427	1376
Alkali/tubp, kg.	215	189	145	169	148	131
	188	160	130	145	121	98
Alkali/tubp, kg. (during washing)	-	-	-	25	24	23
T. alkali/tubp, kg.	188	160	130	170	145	121
Cost of alkali/tubp, Rs.	2068	1760	1430	1870	1595	1331
Cost/tubp	3681	3317	2904	3331	3022	2707
Ubp/tbp	1.048	1.053	1.064	1.044	1.057	1.061
Cost of ubp/tbp, Rs.	3858	3493	3090	3476	3194	2872
Chlorine/tubp, kg.	58	66	88	58	77	85
Cost of Chlorine/tbp, Rs.	348	396	528	348	462	510
Cost/tbp, Rs.	4206	3889	3480	3824	3656	3382

* Based on o.d. straw. Figures in parenthesis based on original straw. **tubp and tub** stands for tonne unbleached and bleached pulp

the pulps as compared to pulp produced from control sample **(Table-2).**

Similarly, rice straw yielded 48.30% and 43.80% unbleached pulp at same level of delignification (Kappa number 23.3 $\pm$ 1.3) under the identical conditions of pulping using 7% alkali charge, for alkali and water washed sample as against 37.20% for control sample **(Table-3, fig.2).** Bleached pulp yield was 46.82% and 41.59% for alkali and water washed sample of rice straws against 35.49% for control rice straw sample. Burst index was improved from 2.63 for control sample to 3.06 and 3.58, tensile index 49.48 for control sample to 49.71 and 56.40 for water washed and alkali washed sample, respectively, under identical conditions of pulping using 7% alkali during pulping. Pulp produced from alkali washed sample using 1% less alkali charge during pulping exhibited comparable tensile index to that of control sample. Pulp produced from water and alkali washed sample using 1% and 2% less alkali charge, respectively, during pulping possessed marginally poor tensile index and comparable burst index 2.56 $\pm$ 0.08 to that of control. Tear index, 4.58 $\pm$ 1.2 was comparable for all pulps except for the pulp produced from water washed sample using 1% lower alkali charge during pulping and was 5.19. Brightness gain was about 4 and 7 points ISO for water and alkali washed sample over control sample.

Further, it is also expected that due to partial removal of silica (inherent and adhered), perenchymetous cells and water and alkali solubles, the inorganic and organic load in the black liquor will be reduced at the same level of pulp yield, consequently, reducing effluent load in black liquor.

On the basis of data generated on unbleached/ bleached pulp yield, an attempt has been made to work out the economic feasibility of water and alkali washing of wheat and rice straw based on assumptions given below. Due consideration has been paid to weight loss during washing of straws. However, authors are unable to include the operational inputs during washing due to non availability of adequate data,

- Cost of wheat straw Rs. 1000 per tonne
- Cost of rice straw Rs. 600 per tonne
- Cost of alkali Rs. 11000 per tonne
- Cost of hypochlorite Rs. 6000 per tonne at 100% available chlorine

Results recorded for raw material requirement **(Table-4, and 5, fig. 3 & 4)** clearly indicated that washed straw require less amount straw not only on washed straw basis but also on original straw basis as compared to control sample except for water washed wheat straw which required marginally higher amount of straw.

Estimated cost Rs. 5263 and Rs. 6124 per tonne of unbleached and bleached pulp of control wheat straw sample was reduced to Rs. 4969 and Rs. 5840 for water washed sample and Rs. 4614 and Rs. 5448, for alkali washed straw sample under identical pulping conditions of pulping using 11% alkali during pulping. It may partialy compensate of cleaning operation charges. However, bonding properties and brightness was appreciably improved on washing. Drop in cost for washed wheat straw pulp using lower chemicals was significant at comparable level of strength properties coupled with improved brightness (Table-2 and 3).

Calculated cost Rs. 3681 and Rs. 4206 per tonne of unbleached and bleached pulp of control rice straw sample was reduced to Rs. 3317 and Rs. 3889 for water washed sample and Rs. 3331 and 3824 for alkali washed straw sample, respectively under identical conditions of pulping using 7% alkali during pulping. Drop in cost was significant in rice straw as compared to wheat straw, however, improvement in strength properties and brightness was low.

As in the case of wheat straw, drop in production cost was further decreased with the decrease in pulping chemical charge at comparable level of strength and brightness with control sample (Table-5).

Thus, to produce same amount of pulp, less amount of washed straws and pulping chemicals would be required. It is also anticipated that washing would improve the effective pulp mill capacity and paper machine runnability, consequently, improving quality and quantity of pulp from these straws.

CONCLUSIONS

On the basis of these experiments, it could be concluded that the washing of wheat and rice straw would improve the quantity and quality of the pulp. However, in the case of wheat straw improvement in quality was more while in the case of rice straw improvement in quantity of the pulp was more pronounce. It is also expected that washing would improve

the effective pulp mill capacity, paper machine runnability and less corrosion to pulp and paper mill equipments. Consequently improving the quantity and quality of pulp from straws. Effluent quality of black liquor will also improve in respect to its treatability.

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