Pulping of Agricultural Residues-Effect of 'Kappa Number' on Economics of Pulping and Bleaching of Rice Straw

Hari Kishore*, A. G. Kulkarni*, Brijesh Kumar* and R. Pant*

ABSTRACT

Number of small pulp mills with capacity ranging from 15 to 30tpd are operating without chemical recovery systems Considering the elevating prices of cooking chemicals, it becomes imperative to use the cooking chemical, i e. sodium hydroxide. judiciously. In the present investigations an attempt has been made to understand the economics involved in delignification in the digester versus delignification in the bleaching process. Studies on the rice straw clearly indicate that by keeping an optimum kappa number around 25 of unbleached pulp. it is possible to save significant proportion of sodium hydroxide than by going in for low kappa number, with higher chemical dosage, during cooking The results also reveal that going for kappa number over 25 is also not economical. Further the estimation of magnitude of total pollution load generated during pulping & bleaching show that higher BOD load is exerted in case of high kappa number pulp compared to pulps of lower kappa number Thus results reveal that by keeping kappa number either higher than 25 or lower than 25 will not be economical.

INTRODUCTION

In small paper mills using agrieultural residues, systematic study relating to economics of removal of lignin during pulping and bleaching has not been made. When viewed in context of absence of chemical recovery, in the present juncture, it becomes imperative to use cooking chemicals judiciously during pulping and at the same time the pulp produced should be easily bleachable with less pollution. With this background the present study was taken up to investigate the optimum degree of delignification required during pulping of rice straw with minimum chemical dosage so that the residual lignin could be removed during bleaching operation. The kappa number of the unbleached pulp was taken as the basis for the extent of delignification.

EXPERIMENTAL

Raw Material : Rrice straw sample was arranged and chopped in required length, varying 2-4 cms. The chopped raw material was made free from dust and taken for proximate chemical analysis and pulping experiments.

Proximate Chemical Analysis : Rice straw sample was evaluated for proximate chemical analysis as per standard procedures given in TAPPI & APPITA.

Pulping : Pulping experiments were carried out in a series digester consisting of six bombs each of 2.5 litres capacity, rotating in an electrically heated polyethylene glycol bath. In order to get unbleached pulps of varying kappa numbrs, soda pulping experiments using 4-8% sodium hydroxide as cooking Chemical were performed under the following constant cooking conditions :

Raw Material taken in each bombs (OD Basis)	gms=200
Raw Material to liquor ratio	=1:5
Cooking Schedule :	
Time for pre-soaking in liquor at ambient temperature, min.	=60
Time for raising temperature from ambient to 100°C, min.	=30
Time for raising temperature from 100° C to 140°C, min.	=60
Cooking time at 140°C, min	=60

*Central Pulp and Paper Research Institute, DEHRA DUN.

At the end of cooking period, the bombs were removed and quenched in water. The bombs were opened and spent liquor was collected after filtering through terylene cloth. The cooked masses were washed thoroughly with cold water, disintegrated and filtered through Bouchner funnel with continuous washing with cold water until filtrate was free from spent liquor. After computing the pulp yield, the pulps wer screened on a 'Serla' flat screen fitted with a 0.25 mm slot width screen. The screened pulps were evaluated for kappa number and strength properties and finally taken for bleaching experiments.

Kappa Number : Kappa number of the screened pulps was determined according to the TAPPI-236-OS-76 Method. 'K-Number was also calculated from the relationship between Kappa number and K-number for rice straw pulps[1] ie;

$$\text{Log Kappa Number} = 1.051 + 0.22\ \text{K—Nnmber}$$

Spent liquor analysis :

Total solids and residual active alkali in the spent liquor were determined according to the methods mentioned in[3].

Bleaching : Pulp bleaching was carried out by single stage hypochlorite. Bleaching dosage were first optimized for unbleached pulps of different kappa numbers in order to achieve bleached pulp brightness 72± 2% ISO. Final bleaching of different pulps were carried out by using optimized dosage of calcium hypochlorite. Pumps were finally evaluated for optical as well as for strength properties.

Pulp evaluation : For evaluating the beating characteristics and subsequent physical strength properties of the unbleached and bleached pulps, the standard methods described in laboratory manual[3] was followed.

Pollution loads : The BOD and COD were measured as described in the standard methods[4].

RESULTS AND DISCUSSION

Raw material analysis : Results of the proximate Chemical analysis of rice straw sample are given in Table—1.

Composition of this particular sample of rice straw more or less the same when compared with the other rice straw samples given in APPENDIX.

TABLE—1

PROXIMATE CHEMICAL ANALYSIS OF RICE STRAW SAMPLE

Particulars	(% on O.D. basis)
Ash content	17.98
Hot water solubility	19.05
Methanol solubility	0.38
N/10 NaOH solubility	48.27
Acid insoluble lignin	12.71
Holocellulose	63.66
Pentosans	17.28

Corrected for ash.

Pulping : Monitoring of kappa number is considered important for uniform bleaching of the pulps. Wide variation of kappa number may lead to the non-uniform bleaching resulting in pulps with lower strength properties. From the available data, it appears that the cooking chemical demand for rice straw, varies significantly from sample to sample for achieving same degree of delignification i.e, same kappa number of unbleached pulps. In orher words, different rice straw samples cooked with same chemical dosage, showed wide variation in unbleached pulp kappa number (APPENDIX).

Considering the variation in chemical dosage required for satisfactory pulping wlth desired kappa number, for rice straw of different variety, it becomes necessary for every pulp mill to optimize in pulping conditions. Kappa number is one of the important variable in deciding the right pulping conditions. Here comes the question what should be the optimum kappa number one should go for. In the present studies an attempt has been made to find the economics involved in delignification in digester versus removal of lignin during bleaching stage. Results of soda pulping of rice straw are given in Table—2.

Pulps produced from this particular rice straw sample, with 4, 5, 6 and 8% sodium hydroxide as cooking chemical showed unscreened pulp yield 64.8, 62.4, 60.8 and 60.2% and rejects content 2.8, 2.6, 1.7 and 1.3 respectively. Corresponding kappa number of the unbleached pulps determined were 44, 31.1, 25.6 and 20.8 respectively. It is important to note that by

'APPENDIX'

RESULTS OF PROXIMATE CHEMEICAL ANALYSIS AND PULPING OF RICE STRAW SAMPLES OF DIFFERENT VARIETY

Particulars	Gujrat-17 (GUJRAT)	Kharvi (GUJRAT)	Basmati (GUJRAT)	Sample from Amravati (TAMILNADU)
Proximate chemical analysis :				
Ash, %	20.9	12.5	17.2	14.6
Lignin, %	13.3	16.3	16.1	16 8
Holo cellulose, %	63.1	63.9	64.6	61 9
Pulping :				
Cooking chemical, NaOH%	10	10	10	10
Cooking Temperature, °C	140	140	140	140
Unscreened pulp yield, %	57.9	52 3	54.3	58.5
Kappa number of unbleached pulp	21.3	33.6	34.2	28.1

TABLE—2

SODA PULPING OF RICE STRAW

Particulars	1	2	3	4
Pulping :				
Cooking chemical as NaOH, % on raw material	4	5	6	8
Unscreened pulp yield, %	64 8	62.4	60.8	60.2
Screen rejects, %	2.8	2.6	1.7	1.3
Kappa number of unbleached pulp	44.0	31.1	25.6	20.8
Spent Liquor Analysis :				
pH	8.6	9.1	9.7	10.4
Total solids, %, w/w	5.76	6.58	7.38	8.25
Residual alkali as NaOH, g/l	Nil	0.40	1.28	1.84

Constant conditions :

Raw material to liquor ratio	=	1:5
Raw material taken in each bomb, gms	=	200, OD
Soaking time at ambient temp., mins.	=	60
Time for raising temperature from ambient to 100°C, min.	=	30
Time for raising temperature from 100°C to 140°C, min.	=	60
Cooking time at 140°C, min,	=	60
H-factor	=	83

increasing the cooking chemical dosage from 4% to 5%, the pulp kappa number could be reduced by 13 points while the increase of cooking chemical from 6 to 8% could reduce the pulp kappa number only by 5 points.

Bleaching: All the four pulps of different kappa number were bleached by single stage hypochlorite, using optimized dosage of bleaching chemical for a brightness target 72±2% ISO. Results of bleaching experiments are given in Table—3.

Requirement of hypochlorite as available chlorine was 18% for the pulp of kappa number 44 as against 8% for the pulp of 25.6 kappa number. Sodium hydroxide used as buffer during bleaching depends upon the dosage of hypochlorite used. Pulp of 44 kappa number required as high as 4.4% sodium hydroxide as against 1.9 and 1.4% respectively for the pulps of kappa number 25.6 and 20.8.

Pollution loads: From the results of pollution loads studies given in Table—4, it was observed that the BOD load exerted in high kappa number pulp was on higher side compared to those from low kappa number pulps This might be due to the fact that the residual lignin in the high kappa number pulp was degraded to smaller fragments during hypochlorite oxidative bleaching and as a result the BOD load was increased. There is not much change in BOD load after 25 kappa number.

Strength properties of pulps: Strength properties of unbleached and bleached pulps are gived in Table–5.

Beating characteristics of the pulps could not be studied because of the very poor freeness values of both bleached as well as unbleached pulps Because of the same reasoning, the strength properties of different pulps at a particular freeness values could not be calculated for comparison. As the initial freeness values of different pulps are more or less the same, a rough comparison of the strength properties at the initial freeness values could not be made possible.

Unbleached pulp of high kappa number '44' showed very poor tear index '3 15' as against tear index '4 45' of moderate kappa number. High kappa number '44' pulp after bleaching with 18% hypochlorite had also shown poor tear index '3.05' as against the tear index '5.15' that of the moderate kappa number '25.6' pulp after bleaching with 8% hypochlorite. Similarly the burst index '2 40' of the latter.

Economics of pulping & bleaching: Cost evaluation of pulping and bleaching chemicals, per tonne of bleached pulp produced, are given in Table—6.

On the basis of cooking chemical per tonne of raw material, the cooking chemical per tonne of the bleached pulp was calculated by considering different kappa number of unbleached pulps. Sodium hydroxide used as buffer and hypochlorite as available chlorine required per tonne of the bleached pulp produced were also calculated for different pulps. Considering the cost of sodium hydroxide @ Rs. 7,000/- tonne and hypochlorite as available chlorine @ Rs. 3,000/tonne, the total cost of chemical per tonne pulping & bleaching chemicals calculated per tonne of bleached pulp produced was around Rs. 1446/–, Rs. 1268/–, Rs 1176 and Rs. 1328 for the pulps with unbleached kappa number 44, 31 1, 25 6 anc 20.8. The chemical cost per tonne of bleached pulp was found minimum if the kappa number of the unbleached was around 25 as evidenced from the Figure—1. Further it is evident that the higher BOD loads in effuents will also involve additional cost for treatment of effluents in case of high kappa number pulps.

TABLE 3

SINGLE STAGE HYPOCHLORITE BLEACHING OF RICE STRAW PULP OF DIFFERENT KAPPA NUMBERS

Particulars	Cook No. 1	2	3	4
Unbleached pulp yield (screened), %	62	59.8	59.1	58.9
Kappa number of unbleached pulp	44	31 1	25 6	20.8
Hypochlorite used as chlorine, %	18	12	8	6
Buffer used as NaOH, %	4.4	3.0	1 9	1.4
Brightness of PulP, % ISO	70.4	73 0	73 0	73 5
Yield loss during bleaching, %	10.2	8.8	7.8	7.4

Constant conditions :
Consistency = 8%
Temperature = 40°C
Time = 2 hrs.

TABLE 4
POLLUTION LOAD GENERATED BY DIFFERENT KAPPA NUMBER PULPS

	PARTICULARS	I	II	III	IV
i)	Cooking chemical as NaOH% on Raw Material	4	5	6	8
ii)	Kappa Number of unbleached pulp	44.0	31.1	25.6	20.8
iii)	Unbleached pulp yield, kgs per tonne Raw Material	620	598	591	589
iv)	Bleached pulp yield, kgs per tonne Raw Material	557	545	545	545
v)	Pollution load during pulping : (per tonne bleached pulp)				
	Total solids dissolved in the spent liquor, kgs.	779	859	896	949
	Organic dissolved in the spent liquor, kgs.	682	737	750	754
	COD	453	490	573	576
	BOD	147	149	150	151
vi)	Pollution load during bleaching : (Per tonne of bleached pulp)				
	Organic dissolved, kgs.	113	97	84	81
	COD , kgs	135	116	41	40
	BOD , kgs	53	46	20	19
vii)	Total pollution load, kgs. : (per tonne of bleached pulp)				
	Organic dissolved kgs.	795	834	834	835
	COD kgs.	588	606	614	616
	BOD kgs.	200	195	170	170

TABLE—5
STRENGTH PROPERTIES OF RICE STRAW UNBLEACHED AND BLEACHED PULPS

Properties	Freeness	Drainage time	Apparent density	Burst index	Tensile index	Strech	Fold Kohler Molin	Tear index	Air res Gurley
	CSF, ml	s	cm^3/g	$kPam^2/g$	Nm/g	%	log	mNm^2/g	s/100 ml.
Unbleached Pulp :									
1	235	12 22	0 66	1 70	37.0	4 2	1 23	3 15	44 3
2	265	10 48	0.66	1 70	33 5	3 4	1.56	3 30	60.8
3	215	12 66	0 66	1 80	37 0	3 8	1.73	4 45	60 5
4	175	14 12	0.68	1.85	34 0	3 4	1.67	3.90	98 0
Bleached Pulp :									
1	175	18 98	0.67	1 95	36 5	4 0	1.30	3.05	109 0
2	150	19 78	0.70	2 25	41.0	4 2	1.76	4 50	147 8
3	155	16 70	0.71	2.40	35 0	5.6	1.91	5.15	123.9
4	145	15 45	0.70	2 60	37 0	5 7	1 74	5.0	151 0

TABLE—6
COST OF COOKING CHEMICALS VERSUS BLEACHING CHEMICALLS

Particulars	Pulp No. I	2	3	4
Cooking chemical, NaOH, % on raw material	4	5	6	8
Kappa number of unbleached pulp	44 0	31 1	25 6	20.8
K-number	26 9	20 1	16.2	12.1
Unbleached pulp yield (screened), kg/t	620	598	591	589
Bleached pulp yield, kg/t on raw material	557	545	545	545
Sodium hydroxide as cooking chemical, kg	40	50	60	80
Sodium hydroxide, kg/t, bleached pulp				
— Used as cooking chemical	71 8	91.7	110.1	146.8
— Used as buffer during bleaching	49 0	32.9	20.6	15 1
Total NaOH, kg/t bleached pulp	120.8	124.6	130.7	161.9
Calcium hypochlorite as chlorine kg/t bleached pulp	200	132	87	65
Cost of chemicals, Rs/t bleached pulp produced* :				
Sodium hydroxide @ Rs. 7 per kg	846	872	915	1133
Cal. hypochlorite @ Rs. 3 per kg	600	396	261	195
Total cost Rs/t bleached pulp	1446	1268	116	1328

*Figures rounded to rupees.

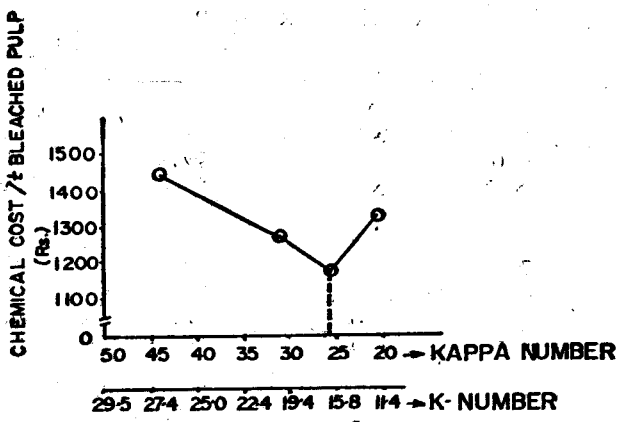

FIG:1, EFFECT OF KAPPA NUMBER OF UNBLEACHED PULP ON THE COST OF CHEMICALS.

CONCLUSIONS :

1. Cost analysis of chemical inputs, during pulping and bleaching showed that the bleached pulp can be prepared by most economic way when the unbleached pulp kappa number is around 25.
2. Higher or lower kappa number of unbleached pulp resulted in higher cost of production of bleached pulps with poorer strength properties.

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