Urea Pulping of Wheat Straw : A Green, Clean, and Environmental Friendly Process

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ABSTRACT

Today agro-based raw materials are playing important role in meeting out more than 50% of the total requirement of 4 million tons of paper and boards in the country. Without a viable chemical recovery unit in most of the small and medium paper mills, huge quantity of sodium hydroxide used in pulping is being drained which generate heavy pollution load. Alternate pulping chemical 'Urea' was tried to replace sodium hydroxide for producing few verities of paper and boards, Earlier urea pulping of rice straw was carried out for its suitability for general grade wrapping paper. Unbleachable grade chemi-mechanical pulp of 68% pulp yield and 35.6 K-Number could be produced with 8% urea dosage which was suitable for wrapping paper of 20-22 burst factor. Studies are now extended on wheat straw. Unbleached pulp of around 28-burst factor could be produced by using 15% urea, which can be used for superior quality liner board. Blending of high strength NDLKC pulp in small quantity (20%) could further improve the tear strength. Blending of above urea pulp of wheat straw with low-grade Indian OCC (old corrugated container pulp of 15 BF) in the ratio 50:50 resulted improvement in burst factor of the blend (BF22).

INTRODUCTION

Ever increasing demand of the paper, board and newsprint in the country, and the limited in the availability of forest based raw materials like wood and bamboo, the use of alternate raw materials mainly agro based raw materials is increasing day by day. Amongst agro - based raw materials, bagasse, rice straw, wheat straw, grasses etc. are more commonly used raw materials while kenaf, jute, leaf fibers etc. have come into commercial use only recently. Out of the total demand of four million tons of paper and board, more than 50% is being produced from agro based raw materials mainly in small and medium size paper mills. (Capacity ranging from 10-100 TPD). Most of these mills are using sodium hydroxide and combination of sodium hydroxide and sodium sulfite as cooking chemical for agro based raw materials. During pulping about 50% of the organics of the raw materials get dissolved and goes in the spent liquor generated.

Sodium hydroxide and sodium sulfite used as cooking chemical also goes in the spent liquor in the form of sodium derivatives of the organics mainly lignin.

Because of non availability of viable chemical recovery unit in most of these paper mills in the country,

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huge quantities the spent liquor generated is being drained which is causing very huge loss of sodium hydroxide and sodium sulfite, presently costing around Rupees 5000 million a year.

In addition to this, the liquor drained is generating very heavy pollution load, since most of these paper mills are not having efficient effluent treatment facilities. However some of the mills are using their soda spent liquor for generation of biogas in order to take the advantage of high BOD load for biogas generation.

Considering the above facts it becomes important to find out alternative pulping processes those are economically viable and environmental friendly atleast for few verities of paper and board. There is a need to explore the possibility of obtaining bleachable grade chemical pulp for writing, printing and many other grades of paper as well as for unbleached semi chemical pulps to produce wrapping and packaging paper, which are in great demand because of recent restriction imposed on the use of polythene carry bags.

Literature survey revealed that in developed countries, ammonia pulping has been tried (1, 2) for the production of high yield chemi-mechanical pulp of hardwods and encouraging results were obtained but this could not be commercialized. Alternatively, urea which is also a nitrogen based compound and which gives ammonia on decomposition was also tried (3) as pulping chemical for producing chemi-mechanical pulp from wood saw dust with an added advantage to dispose the pulp effluent to agricultural fields as a source of fertilizer.

Seeing the effectiveness of urea as a pulping chemical on woody raw materials and also the possibility of utilizing the pulping effluent as a source of fertilizer in agricultural fields, it is borne in mind that urea can be tried as a pulping chemical for the agro based raw materials like rice straw, wheat straw and bagasse etc. In case of its effectiveness it can be recommended for the small and medium paper mills to produce at least few grades of paper.

As most of the paper mills in the country are situated far from the city area and they are very near to the agricultural fields, the pulping effluent generated can be easily disposed in agricultural field as a source of fertilizer without adding any effluent load.

Out of the different agricultural residues used in the smal paper mills like rice straw, wheat straw and bagasse, earlier studies were conducted on rice straw for the production of semi chemical pulp suitable for general grade wrapping paper and very encouraging results were obtained (4,5). The pulp produced was suitable for the production of wrapping paper of 20-22 burst factor with the added advantage of utilizing sodium free spent liquor together with pulp washing for irrigation purpose in the agricultural field.

Inspite of encouraging results there is a delay in its commercial application because most of the mills don't have facilities of high consistency refining of the cooked mass. However, very recently, one mill at Hyderabad had tried by using its existing facilities for refining i.e. beater, and got satisfactory results. We are looking for a mill either equipped with high consistency refining facilities or ready to arrange for the commercial trial.

Studies are now initiated on wheat straw using urea as a pulping chemical in order to find out its suitability over the conventional soda process for the production of better quality kraft liner board. Studies are also extended to use different grades of waste paper pulp along with the wheat straw urea pulp in order to improve the physical strength properties of the resultant pulp blends.

EXPERIMENTAL

RAW MATERIAL

Threshed wheat straw was purchased from local market and kept in polythene bags to attain uniform moisture. It was taken for carrying out the pulping experiments.

PULPING

Pulping experiments were carried out in a series digester consisting of six bombs, each of 2.5 litter capacity, rotating in an electrically heated polyethylene glycol bath under the constant cooking conditions as indicate below:

Raw material taken in each bombs (BD), gm	200
Raw material : liquor ratio	1:5

COOKING SCHEDULE

Time to raising temp. 100°C, min	30
Time to raising temp. from 100°C to 165°C, min	100
Time at temp. 165°C, min	60

The cooking chemicals used were 15% urea and 20% urea on the OD basis of raw material. In a separate experiment 10% urea with 5% sodium hydroxide was also used. Soda pulp using 8% sodium hydroxide was also produced to compare the pulp qualitities obtained from urea and also from urea along with sodium hydroxide cooked pulp.

At the end of cooking period, the bombs were removed and quenched in water. The bombs were opened and the spent liquor separated by filtering the same through a terylene cloth. The cooking masses were processed to obtain pulps. After thorough washing, the pulp yield was determined for each pulp.

SCREENING OF THE PULP

After thorough washing, the pulps were screened in laboratory 'Serla' screen by using 0.25 mm slot width mesh.

DETERMINATION OF PULP 'K' NUMBER

After screening the pulp, 'K' number was determined as per standard procedures.

SPENT LIQUOR

The spent liquors were analysed for BOD and COD according to standard procedures.

EVALUATION OF STRENGTH PROPERTIES OF UNBLEACHED PULP

Physical strength prorties of the different pulps produced as well as that the blends were evaluated as per the standard procedures.

Table-1

Urea pulping of wheat straw

Sl.	Parameters	UP-1	UP-2
1	Urea added (%)	20	15
2	Pulp yield %	70.0	70.6
3	Screen rejects (%)	1.7	1.8
4	BOD of liquor (g/l)	--	22
5	COD of liquor (g/l)	--	52

BLENDING OF THE PULP

Wheat straw pulp produced by using 15% urea was blended with NDLKC pulp produced by using 5% sodium hydroxide in the ratio 80:20. Same wheat straw pulp was further blended with the pulp obtained by slushing of low -grade Indian OCC, old corrugated container in the ratio 50:50.

RESULT AND DISCUSSION

Table-1 indicates the results of urea pulping of wheat straw using different dosage of urea under constant cooking conditions A pulp yield of 70.6% and 70.0% was obtained by using 15% and 20% urea dose on raw material respectively.

Table-2 indicates the physical strength properties of the pulps produced from 15% and 20% urea. The beating characteristics and physical strength properties of the two pulps were found more or less the same. Pulp \produced with 15% urea showed encouraging

Table-2

Physical strength properties of wheat straw pulp cooked with urea

Pulp	PFI (rev)	Freeness ml, CSF	Burst Index kPam²/g	Tensile Index Nm/g	Tear Index mNm²/g
20 % Uera	0	445	1.50	36.0	4.25
	500	270	2.50	51.0	4.10
	1000	200	2.95	54.0	3.70
15% Urea	0	455	1.40	31.0	4.95
	500	310	2.35	43.0	4.25
	1000	255	2.75	51.0	4.00

Table-3

Pulping of wheat straw using and mixture of soda and urea

Sl	Parameters	UP - 2	UP - 3	CP - 1
1	Urea added (%)	15	10	--
2	NaOH added (%)	--	5	8
3	Pulp yield %	70.6	68.3	64.4
4	Screen rejects (%)	1.8	1.5	1.7
5	BOD of liquor (g/l)	22	--	28
6	COD of liqour (g/l)	52	--	81

physical strength properties. At freeness level around 250 ml CSF the pulp produced showed 2.75 burst index, 51.0 tensile index and 4.0 tear index or indirectly 28.1 BF, 5.2 km breaking length and 40.8 tear factor.

Table -3 showed the comparison of the results of urea pulping with the soda as well as with soda/ urea pulping. 15% urea pulping of wheat straw showed much high yield (70.6%) against 8% sodium hydroxide pulp yield (64.4%) as well as against 10% urea together with 5% NaOH pulping yield (68.3%).

Table-4 indicates the physical strength properties of the pulps produced from urea, soda and urea together with soda pulping. Comparison of the results, shows the pulp produced with 10% urea together with 5% sodium hydroxide showed better properties specially burst index. Pulp produced with 8% sodium hydroxide showed still better properties like burst index, tensile index and tear index compared to pulp produced with 15% urea.

Table -5 indicates the physical strength properties of wheat straw pulp cooked with 15% urea and NDLKC pulp cooked with 5% NaOH and that of 80:20 wheat straw: NDLKC blend. It is evident from the table that NDLKC pulp showed high tear index 8.3 (tear factor 85) and burst index 4.0 (burst factor 42) at freeness level 250 ml CSF. Blending of 20% NDLKC pulp with 80% wheat straw pulp showed around 20% increase in the tear strength of blend as evident from the table.

Table-6 shows the results of physical strength properties of the low grade Indian OCC, old corrugated container, pulp and that of 50:50 blend of this pulp with the wheat straw pulp produced with 15% urea. The pulp obtained from low grade Indian OCC, old corrugated container, was found to be of very poor

Table-4

Physical strength properties of wheat straw pulp produced by using soda, urea and mixture of soda and urea

Pulp	PFI (rev)	Freeness ml, CSF	Burst Index kPam²/g	Tensile Index Nm/g	Tear Index mNm²/g
15% Uera	0	455	1.40	31.0	4.95
	500	310	2.35	43.0	4.25
	1000	255	2.75	51.0	4.00
10% Urea + 5% NaOH	0	505	2.15	36.0	4.65
	1000	315	2.75	54.0	4.20
	2000	210	3.40	58.0	4.10
8% NaOH	0	450	2.20	47.5	5.00
	1000	250	3.75	69.0	4.60

Table-5

Improvement of tear strength of urea cooked wheat straw pulp by blending NDLKC

Pulp	PFI (rev)	Freeness ml, CSF	Burst Index kPam²/g	Tensile Index Nm/g	Tear Index mNm²/g
15% Uera	0	455	1.40	31.0	4.95
	500	310	2.35	43.0	4.25
	1000	255	2.75	51.0	4.00
NDLKC	0	570	1.8	30.8	10.8
5%	1000	370	3.2	46.0	9.6
	2000	250	4.0	56.4	8.3
NDLKC:	0	425	1.70	30.0	6.00
Wheat straw	500	310	2.50	42.0	5.60
20:80	1000	250	2.70	46.0	5.05

Table-6

Improvement of burst strength of low grade waste paper pulp by blending urea cooked wheat straw pulp

Pulp	PFI (rev)	Freeness ml, CSF	Burst Index kPam²/g	Tensile Index Nm/g	Tear Index mNm²/g
15% Uera	0	455	1.40	31.0	4.95
	500	310	2.35	43.0	4.25
	1000	255	2.75	51.0	4.00
Low grade	0	455	0.90	19.0	5.50
W/P (Indian)	500	240	1.50	27.5	5.40
Slushed only	1000	200	2.10	36.0	5.20
W/P (Indian):	0	465	1.0	16.5	4.50
wheat straw	500	250	2.20	31.0	5.45
50:50					

burst index 1.5 (burst factor 15.3) at around 250 ml CSF compared to 28.1 BF that of urea pulp. Blending of these two pulps showed burst index 2.2 (22.4 BF) of the pulp blend.

Table-7 indicates the comparison of the effluent quality and cost comparison per ton of the pulps of urea pulping over the conventional soda pulping. It is evident from the table that BOD and COD load of urea pulping spent liquor was less than soda pulp. More over the cost of the chemicals per ton of pulp produced was also much lower than the conventional soda pulp, though the physical strength properties of the soda pulp produced by using 8% sodium hydroxide were found some what better in comparison with that of the pulp produced by using urea pulping.

CONCLUSION

Unbleached pulp of around 28-burst factor could be produced by using 15% urea, which can be used for superior quality liner board. Blending of high strength NDLKC pulp in small quantity (20%) could further improve the tear strength. Blending of above urea pulp of wheat straw with low-grade Indian OCC, old corrugated container, pulp of 15 BF in ratio 50:50 resulted improvement in burst factor of the blend (BF 22). In addition, the soda free and nitrogen rich

Table-7

Economical consideration of urea pulping of wheat straw over soda pulping

Sl	Parameters	Pulping process	
		Soda	Urea
1	**Cooking chemicals on raw materials, %**	8.0	15.0
2	**Pulp yield, %**	64.4	70.6
3	**Effluent properties***		
	- BOD kg/ton of pulp	218	155
	- COD kg/ton of pulp	632	368
	Sodium concentration # kg/m^3	0.467	nil
4	**Strength properties of pulp at 250 ml CSF**		
	- Breaking length (meter)	7038	5202
	- Tear factor	47	40.8
	- Burst factor	38.3	28.1
5	**Cost analysis**		
	- Pulping chemical used per ton of raw material, kg	80	150
	- Pulp produced kg	644	706
	- Pulping chemical used per ton of pulp, kg	124	212
	- Present cost of pulping chemicals per kg	14	4.50
	- Cost of pulping chemical Rs. per ton of pulp.	1736/-	954/-

*** The sodium free pulping spent liquor can be used for irrigation purpose.**
 # Considering effluent volume 150 m^3/t of the pulp.

Annexture - Conversion of paper testing data

From SI unit	To obsolescent unit	Multiply by
Tensile index, Nm/g	Breaking length, km	0.102
Burst Index, kPam^2/g	Burst factor	10.2
Tear Index, mNm^2/g	Tear factor	10.2

pulping effluent from urea pulping can be utilized for irrigation purpose.

Detailed study on the utilization of the urea pulping spent liquor is being undertaken in order to find out its suitability for irrigation purpose and also its impact on soil fertility etc.

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