Pulping of Rice Straw by Pollution Free Organosolv Process

Guha S R.D.,* Sirmokadam N.N.,* Goudar T.R.* and Dhopeshwar Rohini*

ABSTRACT

The paper records the results of an investigation on the pulping of rich straw by pollution free organosolv process. Optimum results were obtained using aqueous ethanol (1 : 1) and ethylenediamine (6% on solvant volume basis) at 120°C. for 2 hours at atmospheric pressure after prehydrolysis. The pulp yield was 51.0 percent and kappa number 23.4. The strength properties of standard sheets made from the pulp were satisfactory. High degree of solvent recovery was noticed.

INTRODUCTION

Organosolv delignification process can provide sulphur-free pulping technology and totally avoids pollution by sulphur compounds. Due to low surface tension, organic solvents can penetrate faster into the cell wall and thus achieve efficient hydrolysis of lignin-carbohydrate bonds. Due to organophillic nature of lignin, there can be selective delignification, and methods could be flexible for various cellulosic materials. The above insight in reaction mechanism formed the genesis of organosolv technology in the production of pulp and paper[1]. A number of organosolv delignification methods have been explored for avoiding loss of carbohydrates during delignification[2-8]. Ethanol and ethylenediamine (EDA) have been found to be an ideal pair of solvents for selective extraction of lignin from lignocellulosic materials. EDA provides needed basicity to form quinone methide and ethanol helps in hydrolysis of carbohydrate-lignin bonds so that lignin is easily extracted by the solvent mixture.

Organosolv pulping research has been mainly directed to softwoods and temperate hardwoods. This prompted the authors to explore the possibility of using organic solvents like ethanol-EDA for selective delignification of Indian raw materials. As an initial step, rice straw, which is one of the main agricultural residues used in India by small paper mills, was taken up for investigation by organosolv pulping.

RESULTS AND DISCUSSION

The Proximate Analysis of a sample of rice straw, collected locally from nearby paddy growing area of Dandeli town, was done according to TAPPI standard methods. The results are given in Table I. The results show that rice straw contains a significantly high percentage of hemicelluloses and silica compared to our conventional raw material, bamboo.

TABLE I
Proximate Analysis of Rice Straw

Serial No.	Property	% on o.d. raw matesial
1	Ash content	16.4
2	Cold-water solubility	13.7
3	Hot-water solubility	16 9
4	1% NaOH solubility	50.5
5	Alcoho-benzene solubility	8.1
6	Holocellulose	65.1 (Ash corrected)
7	Llgnin	9.0 (Ash corrected)

The chopped rice straw, 10 g. on o.d. basis was boiled with 0.5% sulphuric acid with a bath ratio of 1:20 for 2 hours, filtered and washed with hot water. The material was pressed to remove water and than transferred to 500ml round bottomed flask and solvent

*Bangurnagar Degree College. Dandeli

mixture (1:1 aqueous ethanol and ethylenediamine in different proportions) was added to maintain bath ratio of 1:12 (based on original o d. raw material). The flask was kept in an oil bath at 120°C. and refluxed for varying periods. At the end of the pulping period, the materials was filtered and the liquor pressed to remove spent liquor. The pressed cake was disintegrated in water, filtered, washed and the yield of pulp and kappa number were determined. The results of variation of cooking time are given in Table II and of variation of %EDA are given in Table III. The increase in cooking time, as expected, increases the delignification and reduces the yield of final pulp and the kappa number. A time of 2 hours seems to be optimum when 6% EDA is used. The decrease in EDA, as expected decreases the delignification and increases yield of final pulp and the kappa number. Here also 6% EDA appears to be optimum. Under these conditions a yield of 51.0% and a kappa number of 23.4 was obtained. A large quantity of pulp was made under these conditions for study of fibre morphology and strength properties of pulp beaten to 40° S.R.

TABLE II.

Effect of cooking time in organosolv pulping of rice straw

Serial No.	Cooking time (min.)	Unbleached pulp yield % on o d. raw material	Kappa Nnmber of pulp
1	30	56.9	31.9
2	60	55.0	29.8
3	90	54.8	27.6
4	120	51.0	23.4

Note : EDA 6% on solvent volume basis
Bath ratio 1 : 12

TABLE III

Effect of % EDA in Aqueous Ethanol-EDA mixture on organosolv pulping of rice straw

Serial No.	EDA on solvent volume basis, %	Unbleached pulp Yield on o.d. raw material, %	Kappa Number of pulp
1	8	49.5	18.2
2	6	51.0	23.4
3	4	51.9	30.0
4	2	52.0	32.7

The average fibre length was found to be 1.1 mm width 0.05 mm. This shows that rice straw is short fibred compared to bamboo and admixture of some long fibred pulp may be necessary for smooth running on a paper machine.

The solvent ethanol was recovered from the spent liquor by vacuum distillation.

The pulp was beaten in a Lampen mill to 40° S.R. and handsheets of 60 g.s.m. were made on the Standard British Sheet Machine. Physical strength properties were determined according to Tappi Standard Methods. The results are given in Table IV. The strength properties are slightly inferior to those obtained from rice straw by soda process. This may be attributed to the retention of significant amounts of silica with the pulp leaving the spent liquor with minimum silica content. The high silica content in the soda waste liquor is one of the main difficulties in soda recovery.

TABLE IV

Properties of standard sheets made from pulp at Serial No. 2 of Table III beaten to 40° S.R.

Serial No.	Property	Value
1	Breaking length	3200 metres
2	Stretch	2.0%
3	Burst factor	19.0
4	Tear factor	39.0
5	Folding endurance	4 double folds
6	Air porosity	74 sec/100 ml. air
7	Ash	20.5%
8	Viscosity	10.6 cp. (CED)

Further work on recovery of solvents, conversion of lignin to useful intermediates and effect of catalysts are in progress. We also propose to study other raw materials and other organic solvent systems.

CONCLUSIONS

(i) Rice straw, being available abundantly at paddy growing areas, can be a very good source of raw material for small paper mills making writing and printing papers.

(ii) Organosolv pulping of prehydrolysed rice straw using aqueous ethanol-EDA gave good delignification with least degradation of cellulose. A good yield of 51.0% with low kappa number of 23.4 could be obtained under optimum conditions. The strength properties of the pulp were satisfactory.

(iii) The lignin can be recovered without much degradation from the spent liquor as a byeproduct.

(iv) The process can become commercially viable as a high degree of solvent recovery was noticed.

(v) For smooth runnability on the paper machine, it may be necessary to add some long-fibred pulp to the rice straw pulp.

(vi) The process is pollution free as no sulphur containing chemicals are used, and the solvent and lignin can be easily recovered from the spent liquor.

ACKNOWLEDGEMENTS

The authors are grateful to the Dandeli Education Society which financed the project, to the Principal, Bangurnagar Degree College for providing facilities for conduct of the work, and to Dr. R. G. Nayak, Technical Director, Mishal Paper Mills, Shri H.G. Kulkarni, Superintendent, Central Laboratory, West Coast Paper Mills, Shri P.V. Shirahatti and Shri S. Seshachala Rao, Senior Chemists, Research Centre, West Cost Paper Mills for useful discussions.

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