Production of Paper Grade Pulp by Organic Acid Based Pulping of Wheat Straw

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Due to limited availability of conventional forest based paper making raw materials like wood and bamboo, use of alternative raw materials mainly agro residues is increasing day by day. Wheat straw is a cheap substitute for wood raw material and can be used for manufacturing writing and printing paper with a required brightness level of above 80%. To develop less polluting alternatives for the conventional pulping, In the present study a pulping process using formic acid, acetic acid and water to separate cellulose from wheat straw has been investigated. The process is suitable for agro-residues containing high silicon as the silicon compounds present in non-wood fibres are not removed from the pulp during cooking. A series of pulping experiments were carried out to study the influence of, percentage of formic acid and acetic acid in the pulping liquor, pulping time and liquor to dry matter ratio, on the delignification rate and other characteristics of the pulp. The pulp obtained was subjected to oxygen delignification followed by short sequence DE_pDP elemental chlorine free bleaching with chlorine dioxide and peroxide. Results showed that wheat straw pulp cooked using formic acid, acetic acid and water could be bleached to a suitably high brightness while retaining good mechanical strength properties required for writing and printing grade paper.

Keywords : Wheat straw, Formic acid, Acetic acid, Pulping, ECF bleaching

INTRODUCTION

Due to limited availability of conventional forest based paper making raw materials like wood and bamboo, use of alternative raw materials mainly agro residues is increasing day by day. Wheat straw is a cheap substitute for wood raw material and can be used for manufacturing writing and printing paper with a required brightness level of above 80%. But it has a major limitation of poor strength properties, which are reduced further in conventional bleaching processes using elemental chlorine and hypochlorite. Agro residues used in conventional pulping process causes several technical and environmental problems. One of the major problems is the dissolution of silicon compounds into the alkaline cooking liquor. The removal of silica is difficult and uneconomical which in turn led to high pollution load. To overcome these difficulties, in the recent past, significant efforts have been made towards using organic solvents to produce chemical pulp from high silica content non wood raw materials [1-6]. It has been shown that [5,6] plant matters breakdown in formic acid/ acetic acid/ water environment and also retain silicon in the unbleached pulp that was initially present in the raw material. This method generates lesser pollution load than other existing methods. In this investigation wheat straw was subjected to a series of pulping process where formic acid, acetic acid and water have been used as pulping chemical and dose of chemicals has been optimized. Recent trend in bleaching is to shift to elemental chlorine free (ECF) bleaching due to its environment friendly nature. For applying ECF bleaching economically it is advisable to use 'oxygen delignification' as pre bleaching stage. It reduces kappa no. of pulp significantly and thus reduces bleach chemical demand in further bleaching stages. Therefore, in the present investigation wheat straw pulp obtained with optimized process conditions was oxygen delignified and subjected to DE_pDP bleaching sequence.

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MATERIAL & METHODS

Locally available wheat straw was collected, washed with water, air dried, grinded and the fraction passing through a 45 mesh but retained over 85 mesh, was selected. The extractive content and other chemical analysis were performed as per standard TAPPI methods. Proximate analysis of air dried wheat straw are as follows: moisture, 11.9; alcohol-benzene solubility, 3.9; hot water extractive, 7.9; 1% NaOH solubility, 39.2; lignin,17.9; ash, 7.6; silicon, 4.54 and holocellulose, 66.7 %.

Pulping experiments were carried out in a rotary digester consisting of three bombs of 2.5 ltr capacity each. Wheat

Table 1

Effect of formic acid concentration in the cooking liquor and cooking time on unbleached pulp properties.

L/M=15/1 fa/aa/water (% v/v)	Time (hr)	Yield (%)	Rejects (%)	Kappa No.
20/60/20	2	23.56	25.38	52.62
	3	31.53	20.17	46.84
	4	34.12	14.45	37.76
30/50/20	2	34.24	16.16	34.24
	3	42.82	12.81	29.26
	4	40.45	12.32	28.62
40/40/20	2	39.78	15.28	31.65
	3	37.66	13.86	28.34
	4	33.15	12.14	27.54

Table 2

Effect of L/M ration on pulp properties

L/M ration	Yield (%)	Rejects (%)	Silica retention (%)	Kappa No.
10/1	36.65	16.84	-	36.13
15/1	42.82	12.81	93.2	29.26
20/1	41/27	9.84	89.4	28.14

Table 3

Bleaching conditions maintained at various stages

Stage	Consistency (%)	Temp. (°C)	Time (min)	pH	Peroxide (%)
D	10	70	60	4-5	–
E_P	10	70	60	10.5-11.0	0.5
P	10	85	120	11.0	1.0

straw (30g o.d.) cut approximately into 3 cm length was first impregnated with the cooking liquor at 50°C for 30 minutes. After impregnation cooking was done at 110°C under various conditions as recorded in Table 1 and 2. The time to rise to temperature was set at 30 minutes. The resulting pulp was filtered and washed first with fresh organic acid solution and then with hot water. The fibres were then separated in a defibrator, washed with cold water and screened. Both accept fibres and rejects were collected, dried and analysed (Table 1 & 2).

Oxygen delignification of the wheat straw pulp obtained under optimum cooking condition was carried out in a laboratory digester under following experimental conditions: consistency, 10%; NaOH, 2.0%; $MgSO_4$, 0.1%; O_2 pressure, 7.5 bar; temp,120°C; and retention time, 60 min.

Pulp, after oxygen delignification, was subjected to DE_PDP elemental chlorine free bleaching sequence. All the bleaching experiments were carried out in the laboratory, using batch vessels immersed in constant temperature bath. Bleaching conditions maintained at various stages are recorded in Table 3. In D stage sodium chlorite solution was used to generate chlorine dioxide and pH was maintained between 4 to 5. 70 percent of the total chlorine demand was fed to first D stage and 30% in the second D stage. Oxidative extraction has proved to be a very effective approach to achieve higher brightness pulp [7]. In the present investigation, 0.5 percent hydro-gen peroxide (H_2O_2) was added along with the alkali in E_p stage. Handsheets were prepared in British sheet former under standard pressing and drying conditions and optical and physical strength properties of the bleached pulp was evaluated as per BIS - 1848 and ISO : 1060 specifications.

RESULTS & DISCUSSION

A number of pulping experiments were carried out to study the influence of the formic acid/acetic acid ratio, cooking time and liquor to dry matter ratio (L/M) on the delignification rate and chemical characteristics of the wheat straw pulp. In this study cooking time was varied from 2 to 4 hours for 20, 30 and 40% formic acid while amount of water was kept constant. Table 1 shows that for a particular L/M and cooking chemical ratio, increase in cooking time decreases kappa number and amount of rejects considerably. From this table it can also be seen that increasing the formic acid concentration in the cooking liquor from 20 to 40% significantly improved delignification with decrease in kappa number and rejects. Relatively longer cooking time was required (4 hr) to reduce the rejects to a minimum. As the cooking time varied from 2 to 4 hours, the trend in pulp yield obtained was different for different fa/aa/water ratio used in pulping. For cooking with 20/60/20 fa/aa/water ratio pulp yield increased with cooking time whereas for 40/40/20 fa/aa/water ratio it decreased gradually with cooking time. However, cooking with fa/aa/water ratio of 30/50/20 for 3 hours resulted in highest yield of pulp. To study the effect of liquor to dry matter ratio (L/M) on pulp quality three different L/M ratios were chosen. The pulping results have been shown in Table 2. An L/M ratio above 10/1 was required to sufficiently impregnate the wheat straw and to reduce rejects in cooking. It is also clear that with increase in L/M ratio both kappa number and rejects decrease significantly whereas pulp yield showed a maxima at L/M ratio of 15/1.

As the pulp has to undergo oxygen delignification prior to ECF bleaching, the cooking conditions which resulted in maximum yield and significantly lower kappa number may be considered optimum. Thus the most suitable operating conditions for batch pulping of wheat straw as found in the present investigation are: cooking time, 3hr; L/M ratio, 15/1 and fa/aa/water ratio, 30/50/20 at cooking temperature of 110°C.

Therefore, the pulp cooked under above optimum cooking conditions was subjected to oxygen delignification and subsequent DE_pDP bleaching sequence. The bleaching results indicate that wheat straw pulp cooked under fa/aa/water environment can be bleached through ECF bleaching sequence to achieve high degree of brightness (85.6% ISO) and opacity (94.2%) while retaining very good mechanical strength properties (Tensile index = 80.3 Nm/g, Tear index = 3.2 mNm^2/g) required for the manufacture of writing and printing papers.

CONCLUSIONS

The pulp obtained by cooking wheat straw in a fa/aa/water environment showed good yield, low kappa number and very high silica retention. The retention of silicon products in the pulp will favour the recovery process of chemicals used in pulping process. However, rejects are on a higher side. The oxygen delignified pulp could be bleached in DE_pDP bleaching sequence to a suitably high brightness (~86% ISO) while retaining good mechanical strength properties that could be acceptable in the manufacture of writing and printing grades of paper.

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