

Barley Straw : A Promising Non-Wood Source For Pulp And Paper Making

Mahajan Sushma

ABSTRACT

Barley straw (Hordeum spp) has not enjoyed much favour for pulp and paper making as compared to wheat straw, rice straw and bagasse. Pulping experiments with 10% and 14% alkali charge as Na₂O were carried out at 150, 160, and 170°C. Retention time at above temperature was 60 minutes, 120 minutes and 180 minutes. Kappa No. 24.35±0.65 obtained by two different pulping conditions and kappa no. 10.4 pulps were made into sheets for the determinations of physical strength properties. Pulps obtained possessed good strength properties. It was observed that kappa no. 10.4 pulp possessed better tensile index (99 Nm/g), burst index (6.6 kPam²/g) and tear index (7.0 mNm²/g) as compared to kappa number 24.35±0.65 pulp. Kappa no. obtained at 150°C gives better paper properties as to that obtained at 160°C, keeping other cooking conditions same. Microscopic studies were also carried out. Scanning Electron microscope photographs taken are also presented in the paper. Different cell types present are fibers, parenchyma cells, epidermal cells and annular parenchyma cells.

INTRODUCTION

For the last three decades, there is a constant pressure to explore available non wood resources for pulp and paper making, to meet the raw material demand from the local areas to substitute pulp wood, which is becoming scare and multiple uses of timber in other forest product industries has further forced the pulp and paper industry to seek other cellulosic raw material which are available in sufficient quantities at reasonable price. Wheat straw, rice straw and bagasse are the most abundant cellulosic sources used in pulp and paper industry but barley straw (*Hordeum spp.*) has not enjoyed much favour.

Barley straw is available in the areas where the climate is drier and the soil is poorer. It is grown

during the rainy season, mostly in parts of central plateau and in the rain shadow of the Western Ghats. Barley is the main crop of Rajasthan, parts of Gujrat, and South Punjab. Besides India, barley is cultivated in Iraq, Arabia, Western China and the South Western parts of Siberia in Kazakhstan.

In the present study, experiments were conducted on barley straw for its chemical

**Cellulose & Paper Division
Forest Research Institute,
P.O. New Forest
Dehradun-248 006 (Uttanchal)**

composition, morphology along with its behavior during soda pulping to find out its suitability for pulp and paper making.

EXPERIMENTAL

Raw Material Preparation

Barley straw was air-dried and after removal of nodes cut into 2 to 3 cm. long pieces for soda pulping experiments. It was converted in to 40-60 mesh dust for determination of its chemical composition.

Chemical Composition

Chemical composition determination was carried out for klason lignin, holocellulose and ash content as per standard procedures.

Pulping

Soda pulping experiments were carried out under the following conditions:

Alkali charge (as Na₂O) - 10% and 14%

Liquor : Straw ratio - 8:1

Temperature of cooking - 150, 160 and 170°C

Rate of rise in temperature-19°C/minute from 24°C

Cooking time at maximum temperature - 60, 120, 180 minutes

After cooking, pulps were squeezed and black liquor was collected. pH and residual alkali present in black liquor were determined. Pulps were washed in 200-mesh screen to remove black liquor, disintegrated for two minutes and yield pads were made. After oven drying the yield pad weigh was taken and total pulp yield was determined. Pads were soaked in water and after disintegration, screening was done. Rejects percentage was determined. Kappa no of screened pulps were determined as per TAPPI standard procedure. Standard sheets of 60 gsm from pulp having kappa no. of 24.35±0.65 (cook 1 and 3) and 10.4 (cook 2) were prepared in a British sheet-making machine. Physical strength properties and optical properties of the above sheets were determined as per standard procedures. Fiber length and fiber coarseness were determined using KajaaniES-200 apparatus. Scanning Electron-microscope photographs of pulp samples were taken using JSM-800 model. All the results along with details are reported in Tables 1-7.

Table-1

Chemical Analysis of Barley Straw

Ash, %	6.96
Klason Lignin, %	25.8
Holocellulose, %	60.0

Table-2

Delignification of Barley Straw at 150°C

S. No.	Effective Alkali, %	Cooking Time, Minutes,	Screened Pulp yield, %	Rejects, %	Kappa no.	Black Liquor,	
						pH	RAA.gpl
1.	10	60	54.40	0.10	25.0	11.39	3.50
2.	10	120	53.60	0.05	22.2	11.17	3.01
3.	10	180	53.24	0.06	20.7	11.07	2.89
4.	14	60	51.11	0.04	18.3	12.07	7.86
5.	14	120	50.15	-	14.7	11.97	6.79
6.	14	180	52.80	-	15.2	11.88	5.99

Table-3
Delignification of Barley Straw at 160°C

S. No.	Effective Alkali, %	Cooking Time, Minutes,	Screened Pulp yield, %	Rejects, %	Kappa no.	Black Liquor,	
						pH	RAA.gpl
1.	10	60	52.40	0.25	23.7	10.75	2.58
2.	10	120	52.00	0.10	20.2	10.41	2.40
3.	10	180	51.80	0.10	21.0	10.24	1.79
4.	14	60	49.45		14.4	11.68	6.14
5.	14	120	48.30	0.05	11.7	11.49	4.91
6.	14	180	47.80	0.05	10.4	11.31	4.25

Table-4
Delignification of Barley Straw at 170°C

S. No.	Effective Alkali, %	Cooking Time, Minutes,	Screened Pulp yield, %	Rejects, %	Kappa no.	Black Liquor,	
						pH	RAA.gpl
1.	10	60	50.70	0.15	19.2	10.5	2.58
2.	10	120	50.30	0.10	19.6	10.12	1.44
3.	10	180	50.45	0.55	21.9	10.02	1.23
4.	14	60	47.50	0.05	11.3	11.73	6.06
5.	14	120	46.85	0.10	9.6	11.39	3.69
6.	14	180	45.80	0.05	9.4	11.94	2.81

RESULTS AND DISCUSSION

Chemical Composition

Table-1 shows the results of chemical composition of Barley straw. It has 25.8% klason lignin, 60.0% holocellulose content. Percentage of ash in barley straw is 6.96%, which is comparable to wheat straw. Chemical composition of barley straw shows that it is having a good percentage of holocellulose. Higher ash content will need pre-desilication as in case of wheat straw and rice straw¹.

PULPING

Results of pulping of Barley straw by soda process are depicted in Tables 2, 3 and 4. Barley straw when cooked at 150°C with 10% alkali charge as Na₂O, gives a screened pulp yield of 54.40% to 53.24%, for the time of cooking ranging from 60 minutes to 180 minutes with a very little rejects percentage. Kappa no of above pulps range from 25.0 to 20.7. At 14% alkali charge, screened pulp yield ranges between 51.11% to 52.8% with kappa no values between 18.3 to 15.2. It is observed that increasing the alkali charge from 10% to 14%, kappa

Table-5
Physical Strength Properties of Handsheets Made from Barley Straw

	Cook - 1	Cook - 2	Cook - 3
Effective alkali, %	10	14	10
Time of cooking, min	60	180	60
Temperature of cooking °C	160	160	150
Kappa no.	23.7	10.4	25.0
Screened Pulp Yield, %	52.40	47.80	54.40
Freeness, ml. (CSF)	344	327	406
Apparent density gm/cm ³	1.59	1.38	1.54
Burst Index, kPam ² /g	5.9	6.6	6.2
Tear index, mNm ² /g	5.7	7.0	6.3
Tensil Index, Nm/g	80	99	96
Zerospan Index, Km	15.8	16.5	15.5

Table-6
Optical Properties of Handsheets made from Barley straw

	Cook-1	Cook-2	Cook-3
Brightness, % ISO	32	39	33
Printing opacity	93.7	94.1	92.2
Scattering coefficient	239	287	241

Table-7
Fiber Morphology of Barley straw

Fiber length	Cook-1	Cook-2	Cook-3
Arithmetic Average, mm	0.37	0.35	0.44
Length weighted Average, mm	0.79	0.74	0.87
Weight weighted Average, mm	1.20	1.16	1.35
Coarseness, mg/m	0.110	0.094	0.127

no drop is about seven units at constant time of cooking while raising the time of cooking from 60 min. to 180 min drops kappa no by four units when cooked with 10% alkali charge (Table-2).

Barley straw when cooked at 160°C with 10% alkali charge, gives a screened pulp yield of 52.40% to 51.80% with negligible rejects for time of cooking ranging between 60 min to 180 min. Kappa no of pulps ranges between 23.7 to 21.0 for the above pulps. At 14% alkali charge, screened pulp yields are 49.45% to 47.80% with kappa number between 14.4 to 10.4 for time of cooking of 60 minutes to 180 minutes (Table-3). Increasing the temperature of cooking from 150°C to 160°C, reduces the kappa number by one to two units at time and other cooking conditions being same at 10% alkali charge while for 14% alkali charge kappa no drop is 5 to 3 units.

Barley straw when cooked at 170°C with 10% alkali charge gives a screened pulp yield of 50.70 to 50.45% at 60 min. to 180 min. time of cooking with kappa number from 19.2 to 21.9. At 14% alkali charge, screened pulp yield was 47.50 to 45.80% with no rejects at time of cooking of 60 minutes to 180 minutes. Kappa no drop is from 11.3 to 9.4 (Table-4). Increasing the temperature of cooking from 160°C to 170°C, reduces the kappa number by about 5 units for 60 min time of cooking at 10% alkali charge while at 120 min. time of cooking has no significant effect on kappa no drop and at 180 min of time of cooking increase the kappa no slightly. With prolonged cooking time, increase in pulp yield and kappa no is due to redeposition of lignin on the fiber due to

lower alkalinity. It is comparable to rice straw pulps². At 14% alkali charge, kappa no drop is 3 to 1 units from 160°C to 170°C of temperature of cooking at time of cooking from 60 min to 180 min.

PHYSICAL STRENGTH PROPERTIES

For the determination of physical strength properties unbleached pulps of kappa numbers 24.35±0.65 at 10% alkali charge (cook 1 and Cook 3) and pulp of kappa number 10.4 (cook 2) were taken to make sheets. Their physical strength properties are shown in Table-5. On perusal of Table-5, it is observed that at two kappa number of 24.35±0.65 Tensile index values are 96 Nm/g and 80 Nm/g and burst index values of 6.2 kPam²/g and 5.9 kPam²/g were obtained. The only difference is the temperature of cooking. In case of Cook 1 it is 160°C and for cook 3 it is 150°C. Tear index values (6.2 mNm²/g) at 150°C is slight better than 160°C (5.7 mNm²/g). Pulp of kappa number 10.4 (cook 2) possessed better strength properties (Tensile index 99 Nm/g, burst index 6.6 kPam²/g and tear index mNm²/g, 7.0 mNm²/g) as compared to cook 1 and cook 3 (Table-5).

On perusal of Table-6, it is seen that cook 3 and Cook 1 has almost same percentage ISO brightness (33 and 32), printing opacity (92.2 and 93.7) and scattering coefficient (241 and 239) while cook 2 has higher percentage ISO brightness of 39, scattering coefficient of 287 with slight improvement in printing opacity.

BLACK LIQUOR

From Table 2, 3 and 4 it is seen that at 150°C, residual alkali is 3.50 to 2.89 gpl at 10% alkali charge and 7.86 to 5.99 gpl at 14% alkali charge for the time of cooking from 160 min to 180 min. At the temperature of cooking of 160°C, residual alkali is 2.58 to 1.79 gpl at 10% alkali charge and 6.14 to 4.25 gpl at 14% alkali charge, at the temperature of cooking of 170°C, residual alkali is 1.99 to 1.23 gpl at 10% alkali charge and 5.06 to 2.81 gpl at 14% alkali charge for the time of cooking ranging between 60 and 180 minutes. pH of the black liquor is on the alkaline side in all the experiments.

FIBER MORPHOLOGY:

From Table-7, it is seen that weight weighted fiber length is 1.35mm for cook 3, 1.20 mm for cook 1 (kappa number 23.7) and 1.16 for cook 2 (kappa no

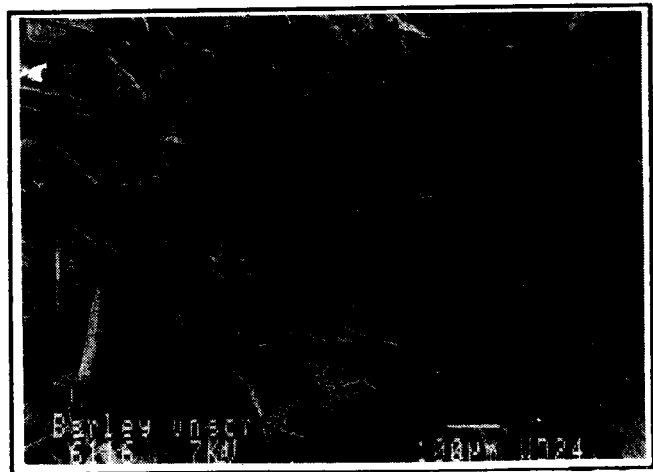


Fig. 1 Barley Straw : Unscreened Pulp

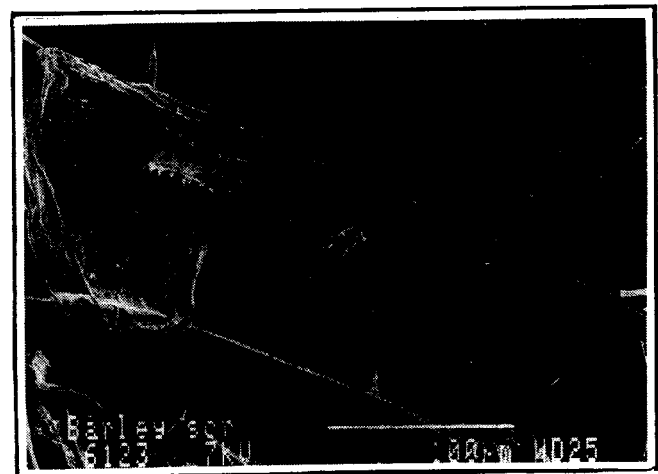


Fig. 2 Barley Straw : Screened Pulp

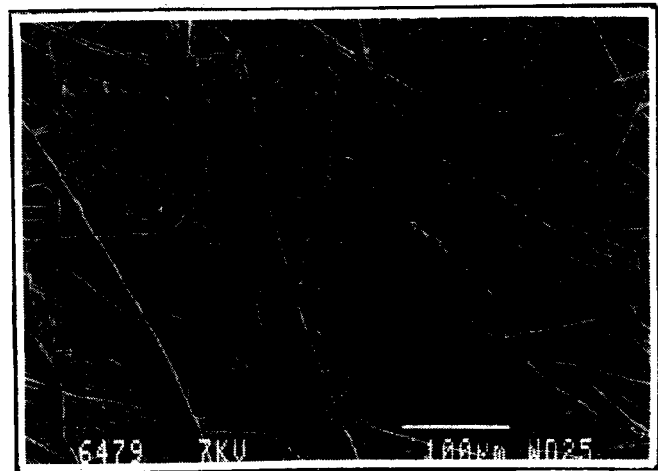


Fig. 3 Barley Straw Pulp

10.4) and fiber coarseness is 0.127 mg/m for cook 3 and 0.094 for cook 2. Fiber length is decreased for more delignified pulps as we proceed from kappa no 24.35±65 to kappa no 10.4.

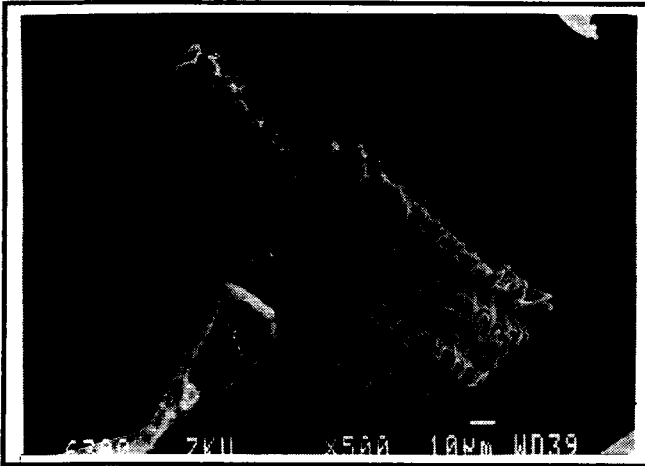


Fig. 4 Barley Straw : Epidermal Cells

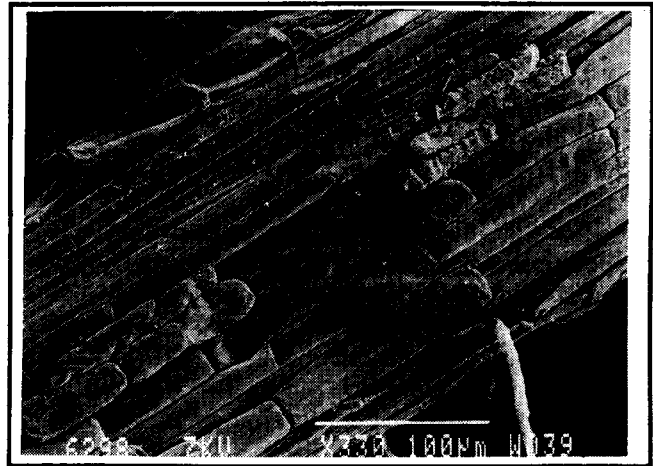


Fig. 7 Part of a Shive showing different cells types

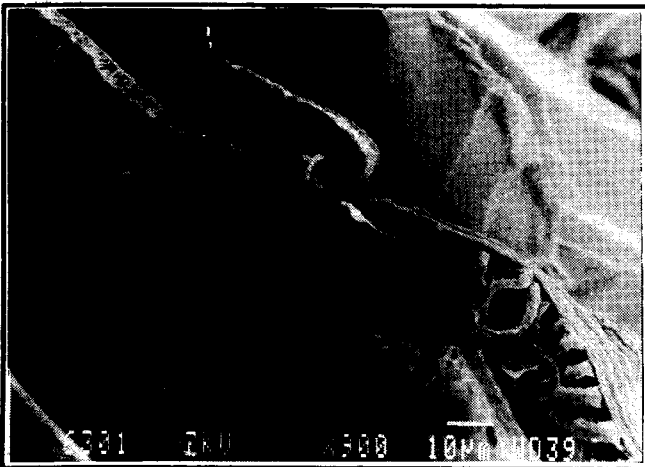


Fig. 5 Barley Straw : annular Parenchyma

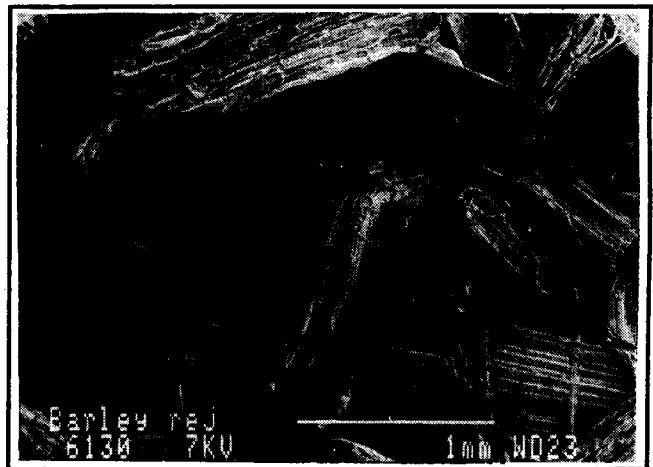


Fig. 8 Pulp Rejects

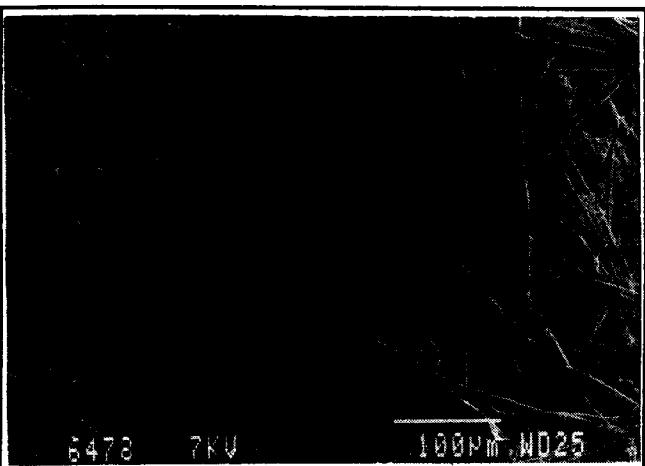


Fig. 6 Barley Straw Pulp of Kappa no. 25

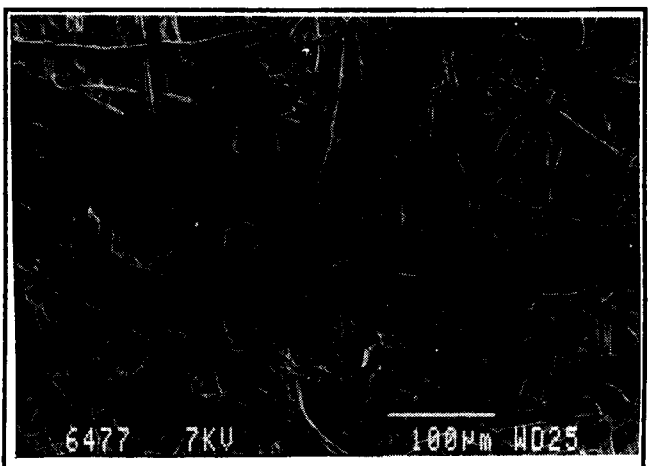


Fig. 9 Barley Straw Paper Sheet as seen from Plate side of Kappa no. 25

Scanning electron microscope photographs shows different types of cells present of barley straw pulp of kappa no 10.4 (Fig-1-5). The cells seen

are fibers, perencyma cells are epidermal cells, epidermal cells are toothed (Fig 4) and annular parenchyma cells (Fig-5) are shown separately. Fig-6-

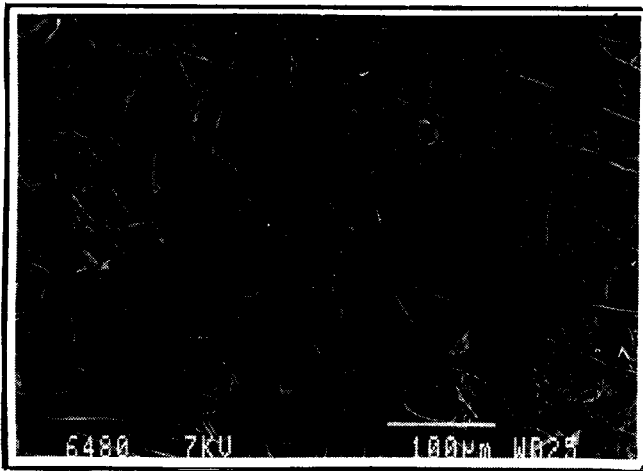


Fig. 10 Barley Straw Paper Sheet as from Plate side of Kappa no. 10.4

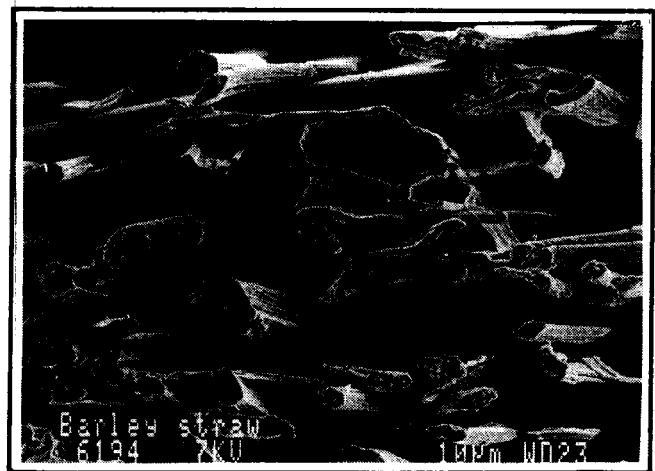


Fig. 12 Cross Section Fibers

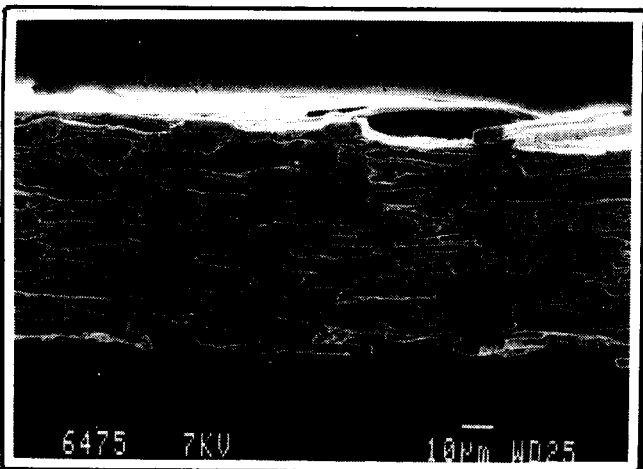


Fig. 11 Barley Straw : Cross section of the paper of Kappa no. 25 pulp

8 shows the barley straw pulp, part of a shive showing different cell types and pulp rejects for kappa no 25.0 pulp. Figure 9 and 10 shows the barley straw sheet as seen from plate side for kappa no 25.0 and kappa no 10.4 Figure 11 and 12 shows the cross section of paper sheet and cross section of fibers of kappa no. 25.0 pulp.

CONCLUSIONS

Barley straw can be soda cooked by 10% and 14% alkali charge as Na_2O for kappa number of 24.35 ± 0.65 and 10.4. It is concluded that kappa number 24.35 ± 0.65 pulps prepared at lower temperature of 150°C possessed comparable strength

as to that of cooked at 160°C for other cooking conditions being the same. At 150°C , pulp yield is about 2% higher as compared to 160°C pulp. Pulp of kappa number 10.4 possessed better pulp and paper properties as compared to kappa number 24.35 ± 0.65 pulps.

ACKNOWLEDGEMENT

Author acknowledge, the Resource Evaluation group of PAPRICAN, Vancouver (Canada) for providing all necessary facilities to conduct this work. Author is also thankful to Dr. S.V. Singh, Head, Cellulose and Paper Division, for going through the manuscript and making necessary corrections and Director, Forest Research Institute for giving necessary permission to publish this work.

REFERENCES

- (1) Semwal, J.P., and Choudhary, A.P. (1994) "Wheat straw -A potential non wood fiber source for writing and printing grade of paper" IPPTA convention issue, Non wood raw material for pulping and paper making, p-42.
- (2) Naithani, Sanjay, Singh, S.V. and Sinha, Anil, K., (1997) "Effect of cooking time at top temperature on properties of pulp and pulping spent liquor in soda pulping" IPPTA, vol-9. No. 1, p-71