Upgradation of Wheat Straw And Rice Straw For Pulp And Papermaking

Mahajan Sushma

INTRODUCTION

Wheat straw and Rice straw offer many oppurtunities for the production of paper to meet the local requirements in the developing countries like India and China, where woody raw materials are not in plenty. These raw materials (straws) are also of concern to the developed countries for the paper and allied products due to environmental concerns as burning of these surplus material is being banned by respective governments and ploughing into the ground is an expensive affair. Pulping and papermaking behaviour of any raw material is influenced by the chemical and morphological structure of that raw material. Straws are quite different chemically and morphologically, which affects the quality and quantity of paper produced, when compared to woods.

CHEMICAL COMPOSITION

Compared with woods, straws usually contain less lignin and cellulose, but more hemicellulose and ash (mostly silicon compounds). The lower lignin content of straws makes it comparatively easier to remove lignin during pulping and bleaching operations. However hemicelluloses and ash, cause problems in pulp washing and also in chemical recovery systems.

Cell, %	Wheat straw	Rice straw
Fibre	62.1	46.0
Epidermis (surface cells)	2.3	6.2
Vessels	4.8	1.3
Parenchyma (thin cell walled cells)	29.5	46.5
Others	1.4	--

Non fibre cells are mostly shorter than fiber cells and their ability to form a paper network is very poor. Most of them act as filler in the paper network and rather have a bad effect on the papermaking process alongwith dry and wet paper properties. Non-fibrous cells creates lots of fines during pulping processes which in turn affects the paper production, quality of paper produced and poor bleachability. Among non-fibre cells, amount of parenchyma cells is very high as compared to other cells. Parenchyma cells are of different sizes and shapes and they can be easily cut into pieces during processing because of very thin structure of their cell walls.

Comparative chemical composition of Wheat straw and Rice straw and of hardwoods

	Cellulose %	Lignin %	Pentosan %	Ash %
Wheat straw	29-35	16-20	26-32	4-9
Rice straw	28-36	12-16	23-28	15-20
Hardwoods	38-49	23-30	19-26	< 1

Morphology of straws

Wheat straw and Rice straw are heterogeneous short fibred material with four main botanical parts: culms, leaves, nodes and grain. These parts differ in structure and chemical composition. Rice straw contains about twice the amount of leaves as compared to Wheat straw. The leaf portion and nodes of the straws contain more non-fibrous cells and more silicon. Cell constituents of non-wood fiber pulps are as follows while in case of wood pulps fibre content is more than 90%.

Studies conducted on wheat straw pulp fibres and fine fraction shows that fine fraction contains more lignin, more pentosan content, less Degree of Polymerisation (DP) and less brightness and more water retention values.

However, if non-fibrous cells which create lots of fines and make processing of these raw materials

Cellulose and Paper Division,
Forest Research Institute,
P.O. New Forest
Dehradun-248 006 (U.P.)

Table-1		
Composition of different botanical parts of Wheat straw and Rice straw		
Part	**Wheat Straw**	**Rice Straw**
Internodes, %	84	65
Nodes & leaves, %	13	28.5
Grains and other foreign material, %	3	6.5

difficult, can be removed before any pulping process, will be a good answer to this problem. Cleaning and upgradation of straws in being done by dry cleaning (dry dusting) and wet cleaning methods, but no work in the direction is reported by removing maximum amount of leaves, nodes and foreign material from the raw material and how these portions effect the pulping and papermaking properties. A study was carried out on bench scale in the Cellulose and Paper Division of this Institute.

METHODOLOGY

Wheat straw and Rice straw from local areas were procured and were upgraded by removing leaves and nodes from the Internodes manually. In case of wheat straw about 13% material was taken out while from rice straw about 20% material in the form of leaves and nodes were taken for the upgradation purposes (**Table-1**). Chemical composition of whole straw (WS) and upgraded straw (NF) for holocellulose content, lignin content and ash were determined as per standard procedures for wheat straw and rice straw (**Table-2**). The whole straw and upgraded straw were subjected to soda cooking under the conditions mentioned in **Table-3** for Wheat straw and **Table-5** for Rice straw. Unscreened pulp yield were determined of pulps. Screening was done in Sommerville pulp fractionator of 0.30 mm slot size. Screened yield and rejects were determined thereafter. Kappa no. values of screened unbleached pulps were determined as per standard procedure. Sheets were

Table-2						
Chemical Composition of Wheat straw and Rice straw						
	Wheat Straw			**Rice Straw**		
	Lignin %	**Holocellulose %**	**Ash %**	**Lignin %**	**Holocellulose %**	**Ash %**
WS*	23.0	62.2	13.5	16.0	67.5	15.8
NF**	19.6	65.6	12.5	14.6	70.9	11.4

* WS - Whole straw
** NF - Upgraded straw

Table-3						
Conditions of delignification of Wheat Straw						
	Whole Straw			**Upgraded Straw**		
Alkali used as active alkali, %	10	10	12	12	14	12
Cooking time, min. at max temp.	0	30	0	30	0	30
Cooking temp., °C	170	170	170	170	170	170
Unscreened yield, %	53.75	52.06	53.10	48.59	41.2	51.86 (45.11*)
Screened Yield, %	46.06	47.52	46.44	45.1	41.2	51.86 (45.11*)
Rejects, %	7.69	4.54	6.66	3.45	Nil	Nil
Kappa No.	23	21	18	16	10	14
Lignin in Pulp, %	3.45	3.15	2.70	2.25	1.5	2.1
Freeness, ml (CSF)	425	415	430	435	455	500

* On whole straw basis

Table-4

Physical strength properties of whole Wheat straw and upgraded wheat straw at 12% alkali charge of unbeaten pulps

Property	Whole straw	Upgraded straw	%Increase
Apparent density, g/cm^3	0.68	0.78	14.70
Tensile index, Nm/g	46.90	66.66	42.13
Tear index, mNm^2/g	2.58	2.65	2.71
Burst index, kPam^2/g	2.99	4.04	35.11
Brightness, % ISO	27.21	36.85	10 Units

made of the pulps at 12% active alkali charge for whole straw and upgraded wheat straw and 8% active alkali charge of whole and upgraded rice straw. Physical strength properties and brightness values were determined. Results are tabulated in **Table-4** and **Table-6** for wheat straw and rice straw respectively.

RESULTS AND DISCUSSIONS

Upgradation of wheat straw and rice straw was done manually in the laboratory. As seen in the Table-1, wheat straw contains about 84% internodes, rest 16% is nodes, leaves, grains and other foreign material. Rice straw is having 65% internodes, rest 35% is nodes, leaves, grains and other foreign material. In the case of wheat straw, during upgradation process, nodes were totally removed, while some amount of leaves were left with the internodes. About 13% of the material is taken out during upgradation process. In case of rice straw about 20% of the material is taken out during upgradation process. Chemical composition of whole wheat straw and upgraded wheat straw reveals that by upgradation, lignin is reduced by 3.4%, Ash by 1.0% and holocellulose is increased by 3.4% (Table-2). While in rice straw, lignin is reduced by 1.4%, Ash by 4.0% and holocellulose is increased by 3.4%. Upgradation is a good indication for improving the pulping characteristics as shown by their chemical composition.

Table-6

Physical strength properties of whole Rice straw and upgraded Rice straw at 8% alkali charge of unbeaten pulp

Property	Whole straw	Upgraded straw	%Increase
Apparent density, g/cm^3	0.57	0.64	24.56
Tensile index, Nm/g	60.85	71.46	17.43
Tear index, mNm^2/g	2.39	2.85	19.24
Burst index, kPam^2/g	3.79	5.04	32.98
Brightness, % ISO	22.00	26.00	4 Units

Whole wheat straw was delignified by sodium hydroxide under the conditions tabulated in Table-3. Upgraded wheat straw was also soda delignified by 12% active alkali as mentioned. Results indicate that with the increase of amount of active alkali, rate of delignification is more. Kappa no. values decreased from 23 to 10, as the amount of alkali is increased from 10%-14%, at constant temperature of 170^{0}C. The amount of lignin retained in the pulps ranges from 3.45% to 1.5%. Upgraded wheat straw pulp when compared to whole wheat straw pulp under the

Table-5

Conditions of delignification of Rice Straw

	Whole Straw				Upgraded Straw			
Alkali used as active alkali, %	8	8	8	8	8	8	8	8
Cooking time, min. at max temp.	0	120	0	30	30	0	30	30
Cooking temp., ^{0}C	100	100	140	140	160	170	170	160
Unscreened yield, %	58.79	50.84	47.36	46.33	46.06	43.53	42.76	49.94 (39.95*)
Screened yield, %	29.38	34.72	43.22	42.50	43.73	42.80	41.70	49.24 (39.39*)
Rejects, %	27.36	16.12	4.14	3.83	2.33	0.73	1.06	0.7
Kappa No.	-	-	34	32	25	22	20	20
Lignin in Pulp, %	-	-	5.1	4.8	3.75	3.30	3.00	3.00

* On whole straw basis

Table-7		
Properties of Fibre fraction and fine fraction of bleached straw pulp		
Properties	**Fibre fraction**	**Fine fraction**
Lignin content, %	1.5	5.3
Pentosan content, %	32.8	34.6
D.P. of Cellulose, %	873	642
Crystalinity index of cellulose	0.20	0.16
WRV, %	176	192
Brightness, %	75	72
Source : Shi-Ju-Kuang and Zhang Jiao, A study on various fractions of chemical wheat straw pulp, p.3, No.1, 1987, China Pulp and Paper.		

identical processing conditions, reveals that kappa no. value is 2 unit less in case of upgraded straw, so is the lignin content of pulp (2.25% whole straw and 2.1% upgraded straw). Canadian standard Freeness of these two pulps is 435 ml and 500 ml respectively. These results shows that by removing fine producing parts of straw, improves the freeness. When we compare the physical strength properties of two raw materials, (whole straw and upgraded straw), it revels that properties are upgraded: Apparent density 14.70%, Tensile index 42.13%, Tear index 2.71%, Burst index 35.11% and brightness value by 10 ISO units. Earlier studies carried out by chinese scientists on wheat straw pulps fibre fraction and fine fraction, also supports this finding (Table-7), that if fine producing cells are removed before the pulping process, strength properties and brightness is improved.

It is very encouraging in the case of wheat straw that loss of the raw material during upgradation process is compensated by yield gain of unbleached pulp (whole wheat straw unbleached pulp yield is 45.1% and upgraded wheat straw unbleached pulp yield is 51.86% and 45.11% on whole straw basis, with the increase in paper properties. The sheets of upgrade straw are better in formation, less in shive content as compared to whole straw. It will also be beneficial for paper mill production and quality of the end product produced.

Whole rice straw was delignified by sodium hydroxide under the conditions tabulated in Table-5. Upgraded rice straw was also delignified by soda process. AT 100°C, about 50% of the raw material is cooked. When the temperature of cooking is increased from 100°C to 140°C, 160°C and 170°C, pulp yield decreases with the decrease in kappa no. at 8% active alkali charge. Whole rice straw and upgraded rice straw results show that under identical cooking conditions of 8% active alkali charge, at 160°C and 30 minute time of cooking, screened yield is 43.73% and 49.24% for whole straw and upgraded straw with the kappa no. drop from 25 to 20. This 5 unit kappa no. drop in upgraded rice straw pulp will require less bleaching chemicals thus less pollution. In case of rice straw, by upgradation, there is 4% yield loss when calculated on original raw material basis. However physical strength properties are improved as apparent density 24.56%, Tensile index 17.43%, Tear index 19./24%, Burst index 32.98% and brightness by 4 ISO units.

Further studies on bleaching are in progress. The main emphasis shall be on development of environment friendly sequences.

CONCLUSIONS

Soda pulping experiments were carried out on wheat straw and rice straw show that upgradation of these material by removing nodes and leaves improves the paper properties appreciably. It was observed that for wheat straw unbleached pulps, tensile index improved by 42.13%, tear index by 2.71%, burst index by 35.11% and brightness by 10 units without any loss in pulp yield, calculated on straw basis (unbleached yield 45.11%). For rice straw, tensile index improves by 17.43%, tear index by 19.24%, burst index by 32.98% and brightness by 4 units. However there is some loss in pulp yield in case of rice straw. Unbleached pulp yield for whole rice straw was 43.73% and for upgraded straw it was 39.39% on whole straw basis.