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Technical Considerations For Rice Straw Based Mini Paper Plants

The paper discusses technical considerations involved in the setting up of a mini paper plant based on Rice Straw as its chief fibrous raw material. The conventional pressure cooking of Rice Straw was compared with Mechano-chemical cooking. Single stage vs multi-stage bleaching of Rice Straw pulps was also studied. Effluent treatment methods for a Mini Paper Mill were briefly discussed,

It is shown that medium strength Kraft papers and ordinary writing/printing papers can be manufactured from Rice Straw pulps admixed with long fibred pulps from bamboo or Kenaf.

Straw is one of the oldest raw materials for papermaking. The first commercial manufacture of paper from straw was in 1831. It is estimated that the annual production (1) of collectable straw in the world amounts to about 900 million tonnes, of which about 550 million tonnes are wheat straw, 180 million tonnes are rice straw and the rest barley oat and rye straw. In view of the global shortage of wood fiber, interest is revived in good old straw pulping.

Rice is staple food in many parts of our country. According to 1961–62 statistics, around 30 million tonnes of rice (2) were produced in about 80 million acres. Assuming that 1.0 tonne of Rice Straw results per every, ton of rice (3), the total rice straw production would have been 30 million tonnes. If only one third of the rice straw produced was made available for papermaking, theoretically 3 million tonnes of paper would have resulted, assuming pulp yield ef 33% on straw. The difficulties in collection, storage and transportation of straw seem so far the main hurdles in exploiting the potential of this raw material for papermaking.

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Rice straw has successfully been used for making various grades of paper and board. Rakta Paper Mills in Egypt and Valaichchenai Paper Mills in Sri Lanka are two of the larger paper mills (around 70 tonnes per day) based on rice straw as main raw material. Rice straw has been reported (4-8) as a suitable raw material for high grade papers, greaseproof papers, and even dissolving pulps.

Mini Paper Plants

Mini paper plants will go a long way towards solving the problem of paper shortage in our country. As is well known, the capital cost per annual ton of paper for a mini paper mill will be Rs. 3500 as against Rs. 10,000 for a 100 TPD mill. Again, the mini paper plant will not have to import expensive foreign equipment. The needs of raw material, chemicals, water, fuel, power, etc. for a mini paper plant do not present serious problems as they do in large paper mills.

In the present situation in our country, a typical mini paper plant may be taken as a mill manufacturing 20 tonnes/day of paper. The present paper includes laboratory evaluation of pressure cooks and mechano-chemical cooks, the effect of single stage bleaching vs multi-stage bleaching and a brief outline of effluent treatments for small paper mills in addition to a general discussion on the selection of suitable equipment for pulp and papermaking from rice straw.

Raw Material Requirements

(for 6,000 tonnes bleached paper per year)

a) Assuming a pulp yield of 40% on rice straw for bleached pulps in mechano-chemical pulping, a 20 TPD mill needs around 15,000 tonnes per year of rice straw. Assuming that 0.5 tonnes of rice straw are available as surplus per acre for papermaking, straw from about 30,000 acres will be needed to sustain the paper mill.

Bleached or unbleached paper grades can be made at machine speeds around 150 metres/min. using 70% straw pulp in the fiurnish, the rest being long fibred pulp from gunny bags, rags, etc. pulped at the mill site or purchased chemical long fibred pulp.

b) **Chemicals :**

i) Caustic Soda 10% NaOH on OD straw in cooking and 2% NaOH on OD unbleached pulp in bleaching operations.

ii) Chlorine (in chlorination/hypo stages) 9% as chlorine on OD unbleached pulp.

iii) Alum (2-4% on pulp stock depending on the hardness of water).

iv) Rosin (0.5-1.0% on pulp stock depending on the grade of paper manufacture.)

v) Talc (10% on pulp stock depending on the paper grade).

vi) Dyes, Gums, etc. depending on requirements.

c) **Water :**

100,000 gallons/ton of paper.

d) **Land :**

5-10 acres of land will suffice for a 20 TPD mill. If the effluent is to be treated, however, more land will have to be provided. This aspect is discussed at length under effluent treatment.

e) **Power :**

1500 KWH/ton of paper

f) **Fuel :**

1.0-1.2 tonnes of coal/ton of paper, depending on the quality of coal.

Choice of Equipment and Process

Due to its bulky nature, high ash and low lignin contents (Table 1 for rice straw of Ukai Songad used in our experiments), rice straw is in a class by itself, different from other straws and grasses. Some of the factors to be considered are :

TABLE 1:—Proximate Analysis of Rice Straw

Sl. No.	Particulars			Results
1.	Moisture		%	7.4
2.	Ash		%	16.1
3.	Cold Water Solubility		%	9.5
4.	Hot Water Solubility		%	12.6
5.	1% NaOH Solubility		%	45.2
6.	Alcohol Benzene Solubility		%	4.6
7.	Lignin		%	12.8
8.	Pentosans		%	22 7
9.	Holocellulose		%	55.6
10.	Alpha Cellulose		%	32.1
11.	Fiber Length		mm	
		Max.		3.45
		Min.		0.30
		Avg.		1.36
12	Fiber Width		Microns	
		Max.		14
		Min.		5
		Avg.		9

TABLE 2:—Analysis of Straw Black Liquor

Sl. No.	Particulars		Black Liquor Characteristics	
			Pressure Cook	Mechano-Chemical Process
1.	pH		11.0	10.6
2.	Total Solids	%	5.4	2.8
3.	Inorganics	%	34	42
4.	Organics	%	66	58
5.	Silica	%	3.4	12.6

Baling and Storage:

Handling of rice straw in view of its high bulk is not easy. Attention must be paid to bale straw at not less than 10 lbs AD. straw/cu.ft , as low density bales donot withstand pressure during handling and transportation costs are higher with lower density. Moisture content of straw at baling should be 10-15, since moisture at this level helps to produce firmer and denser bales as well as minimise microbial attack. Both the chaff and weed contents of the baled straw should be below 5%. To hold weathering losses and microbial attack to the minimum, it will be advantageous to cover the baled straw with tarpaulins or sheet plastics and treat the top tiers of straw with borax or boron compounds.

Straw Cleaning :

Since rice straw contains about 50% leafy material and other contratries, it is essential to preclean the straw fiber before pulping. The advantages are lower chemical consumptions, better fiber quality and easier processing operations. The two cleaning techniques presently available are : (i) the dry method and (ii) the wet method. The wet cleaning method produces a better quality fiber than does the dry method but is more expensive. In the dry method. chopped straw passes through a beating drum, blown through a screen and cyclone, chemically treated in a Kneader and discharged by belt conveyors into digesters. The wet method consists in subjecting the straw to whirling action in a hydra-pulper, removing dust, etc. in a dewatering drum and pressing the cleaned straw to around 40% in a screw press. The decision to choose dry or wet method for cleaning straw depends on the quality of paper envisaged by the entrepreneur of the mini paper plant.

Cooking:

Particularly all rice straw is commercially pulped today by (i) Soda process (ii) Neutral Sulphite process and (iii) Celdecor—Pomilio (Alkali-chlorine) process. The choice of pulping process depends in the availability of the specific cooking chemicals near the mini paper plant at reasonable prices. The alkaline chemical straw pulps have better bursting and tensile strength than do the neutral sulphite pulps; the latter however are freer than the alkaline pulps and are reported nearly as free as sulphite wood pulps.

Due to high bulk of straw, digester packing will be around 100 Kgs/M³ for straw as against 225 Kgs/M³ for bamboo; lhe

TABLE 3:– Cooking Condition For Pressure And Mechano-Chemical Cooks of Rice Straw

Sr. No.	Particulars		Pressure Cook	Mechano-Chemical Cook
1.	NaOH applied on O.D. Straw	%	10	12
2.	Bath Ratio		1:4	1:20
3.	Temperature	oC	140	95
4.	Time to Temp.	Hrs.	3/4	—
5.	Time at Temp.	Hrs.	2½	3
6.	Refined Yield on OD Straw,	%	50	55

TaBLE 4:–Chemical Properties of Techano-Chemical And Pressure Cooked Rice Straw Pulps

Sr.No.	Particulars		Pressure Cooked Pulp	Mechano-Chemical Pulp
1.	Permanganate Number		8.4	13 3
2.	Lignin	%	5.3	7.6
3.	Pentosans	%	15.6	27.2
4.	Alpha Cellulose	%	65.2	61.7
5.	Ash	%	14.8	3.7
6.	Fiber Classification,	%		
	+20	Mesh	11.0	23.1
	—20+50	Mesh	23.3	24.0
	—50+65	Mesh	14.3	10.2
	—65+125	Mesh	4.2	1.4
	—125	Mesh	47.2	38.6
7.	Bleaching Sequence		CEHH	CEHH
8.	Chemical Consumption on OD Unbleached Pulp,			
	i) as Chlorine	%	9.0	10.2
	ii) as NaOH	%	3.0	3.6
9.	Bleached Yield on OD Rice Straw	%	35	44

packing can, however, be improved by adopting techniques such as Va–purge treatment, which also ensures efficient diffusion of the chemicals into the steam treated raw material. Although straw is pulped mostly in batch rotary type digesters, some large mills in Europe and Latin America have successfully used continuous digesters for cooking straw. For a mini plant, going in for a continuous digester will be very expensive.

The low lignin content and open nature of straw suggests the possibility of cooking it in open vessels The mechano-chemical process utilising this principle has been reported to produce straw pulps suitable for corrugating medium in 30 mts, easy bleaching pulps in 45 mts and pulps for insulating boards in 60 mts. The mechano-chemical pulps are produced in higher yields and at lower ash contents than pressure cooked pulps. The mechano-chemical pulp has better beating strength properties than does the pressure cooked pulp.

In the present study, mechano-chemical pulp of rice straw is compared with pressure cooked pulp, both using Caustic Soda as cooking chemical. Table 2 lists the characteristics of black liquors of both the cooks. Pressure cook's black liquor has lesser silica, higher total solids and organics than that of mechano-chemical cook. Digestion conditions for the two cooks are listed in Table 3. The unbleached and bleached yields in mechano-chemical cook are higher than in pressure cook. The pulp characteristics of both the pulps are listed in Table 4. Pressure cooked pulps have 2-3 points higher opacity than do the mechano-chemical pulps but the strength properties of the latter are superior (Table 5). A miniscale paper plant entrepreneur will do well to take a good look at the mechano-chemical process.

Chemical Recovery

In the absence todate of a suitable chemical recovery system for rice straw black liquors even in large mills, it may be advisable for the mini paper mill to reduce its effluent volume by effective in-plant controls and treat the effluent to the minimum acceptable standards for irrigation.

Pulp Refining

The straw pulp from the mechno-chemical cook could be defiberised

TABLE 5:– Strength Evaluation of Unbleached And Bteached Straw Pulps: Pressure And Mechano-Chemical Cooks

Sl. No.	Particulars	Unbleached Pulps		Bleached Pulps	
		Pressure Cook	Mechano Chemical	Pressure Cook	Mechano-Chemical
1.	Freeness, ml CSF	150	150	150	150
2.	Breaking, Length, M	4305	4902	4465	5050
3.	Burst Factor	23.3	30.4	30.6	38.6
4.	Tear Factor	49.5	50.8	60.5	56.0
5.	Double Folds	3	25	24	134
6.	Sheet Density, g/cc	0.55	0.62	0.55	0.56
7.	Brightness, OPV	34	34	79	78
8.	Opacity. Tappi	89	87	90	83

TABLE 6.—Single stage Bleaching vs Multi—Stage Bleaching for Pressure Cooked Rice Straw Pulp

Sr. No.	Particulars	Single Stage Bleaching			Multi—Stage Bleaching		
1.	Bleaching Sequence		H	C	H	H	H
2.	K No.		8.4		8.4		
3.	Chemical Consumption, %						
	1) as Chlorine on OD Unbleached Pulp	9.0	14	6.0	—	2.0	1.0
	ii) as NaOH on OD Unbleached Pulp	3.0	4.0	—	2.0	1.2	0.4
4.	Brightness, OPV	68	75			73	79
5.	Post Colour Number	10.9	11.2			6.5	5.3
6.	Viscosity (0.5% CED), CPS	7.0	5.4			7.2	7.9
7.	Strength at 150 ml CSF						
	Breaking Length, M	4022	3977			4465	
	Burst Factor	26.6	28.5			30.6	
	Tear Factor	58.3	42.9			60.5	
	Double Folds, MIT	10	2			24	
	Sheet Density, g/cc	0.56	0.56			0.55	
	Opacity, Tappi	92	92			90	

in a disc refiner at a consistency around 60% avoiding fibre cutting. This is essential to keep the already low tear in short fibered straw pulps from falling down further.

Washing

Due to the poor drainage of alkaline straw pulps (300 ml CSF against 700 ml CSF for bamboo or wood Kraft pulps), the washing area requirements will be higher for straw pulps than for bamboo or wood pulps. For instance, the output rate of bamboo Kraft pulp on brown stock washers is around 4 tonnes/sq.-metre/24 hours as against 1.5 tonnes for alkaline straw pulps. Also, because of the sticky nature of straw pulps, high pressure showers and synthetic filter cloth are preferred in washing these pulps (9).

Screening

In view of the presence of contraries in straw pulp, through screening facilities must be provided. Sand traps, Jonson screen with finer plates; selectifier screen and centri-cleaners in 2 or 3 stages should be used. The investment for a screening system in a rice straw based mill is proportional to the quality of papers envisaged for manufacture.

Bleaching

Where possible, it is better to go in for multi-stage bleaching involving chlorination, alkali extraction and hypo stages for quality papers. For pulps of around 72 °PV brighness. CEH sequence will do. Table 6 compares single stage bleaching with multi-stage bleaching at 9% total chlorine demand; it was possible to achieve 79 °PV brightness with a P.C. Value of 5.3 in CEHH bleaching compared to 68 °PV brightness at a higher P.C. value of 10.9 in single stage hypo bleaching. Even 14% chlorine on unbleached pulp gave only 75 °PV brightness. The P.C. Value is higher, viz. 11.2; the viscosity is lower (5.4 vs 7.2) and the strengths are lower (DF 2 vs 24). The stronger the bleached straw pulp, the less will be the requirement of long fibred pulp. The mini paper plant will, however, have to balance the advantage of less bleach consumption and stronger bleached pulp in multi-stage bleaching with the additional initial investment needed for equipment in each stage of bleaching.

Stock Preparation

Straw pulp requires practically no refining. The refiners here should be used for final adjust-

TABLE 7:—Strength Evaluation of Bleached Mechano-Chemical Rics Straw Pulps at Different Levels of Freeness

Sr. No.	Particulars	Results		
1.	Freeness, ml CSF	210	150	100
2.	Breaking Length, M	4560	5360	5481
3.	Burst Factor	28.4	32.2	33.8
4.	Tear Factor	75.6	43.5	40.2
5.	Double Folds, MIT	36	55	141
6.	Sheet Density, g/cc	0.45	0.62	0.67

TABLE 8A :—Physical Characteristics of Rice Straw Pulp Blends with Bamboo Kraft Pulps

Sr. No.	Particulars	Unbleached Blends Rice Straw (Soda) + Bamboo Kraft							Bleached Blends Rice Straw (Soda) + Bamboo Kraft						
	Straw	100	90	80	70	60	50	0	100	90	80	70	60	50	0
	Bamboo	0	10	20	30	40	50	100	0	10	20	30	40	50	100
1.	Freeness ml CSF	150	150	155	160	160	170	250	150	150	155	160	160	170	250
2.	Drainage Time, Secs.	44	44	39	30	29	28	12	48	43	39	37	36	28	13
3.	Breaking Length, M	4305	3880	3145	3833	4719	4521	6626	5050	4424	6350	5465	6664	4475	5998
4.	Burst Factor	23.3	19.9	24.8	39.9	31.4	33.7	47.0	38.6	29 0	33.5	46.7	42.1	40.0	42.6
5.	Tear Factor	49.5	67.5	80.6	108	95.2	109	120	56	53.3	60.9	77.4	64 0	62.6	72.3
6.	Double Folds, MIT	25	38	50	56	68	78	171	134	138	141	210	179	72	156
7.	Sheet Density, g/cc	0.55	0.84	0.50	0.55	0.52	0.55	0.62	0 51	0.59	0.54	0.65	0.57	0.50	0.66

ments in stock freeness prior to blending with the long fibred pulps. The long fibred pulp will, of course, go through the conventional steps of stock preparation. Table 7 shows the strength of bleached straw pulp (lab cooked and bleached) at different freeness levels.

Paper Machine

Due to the poor drainage characteristics of rice straw pulps, it is necessary to have a longer wire than in the case of bamboo or wood plups. Further-more, rice straw paper shrinks about 7% compared to 4% shrinkage in bamboo paper. Proper care should therefore be taken in designing the wet end of a paper machine for rice straw based papers.

Due to the weak structure of the paper web, it is not possible to use 100% rice straw pulp in the furnish for manufacturing writing or printing grades at normal machine speeds of 150-200 metres/min.

Table 8A lists the drainage times and strengths of different blends of rice straw pulp with bamboo Kraft pulp. (both bleached and unbleached blends). For both unbleached and bleached blends, a blend of 70% rice straw pulp with 30% bamboo pulp seems good; the tear of this blend is almost equal to 100% bamboo tear. Almost the same trend is shown in Kenaf-Straw blends in Table 8B. Please refer to Figures 1 & 2 also.

Straw pulps have higher opacities (around 92) than do bamboo pulps (around 82) in view of their higher percentage (40% against 30%) and nature of fines. For this reason in printing papers using straw pulp, the need of fillers, etc. will be minimal.

Effluent Treatment:

Even large paper mills based on rice straw do not have chemical recovery systems. An interesting system using ammonia for cooking straws, etc. and the recovery of ammonia was recently proposed (10). As it stands today, it is difficult for a mini paper mill to afford a chemical recovery system. Hence, it may be necessary to treat the effluent to satisfy state of federal laws on pollution. Where feasible, it

TABLE 8B:—Physical Characteristics of Rice Straw Pulp Blends with Kenaf Pulps

Sr. No.	Particnlars	Unbleached Blends							Bleached Blends						
		Rice Straw (Soda) + Kenaf Kraft							Rice Straw (Soda) + Kenaf Kraft						
	Straw	100	90	80	70	60	50	0	100	90	80	70	60	50	0
	Kenaf	0	10	20	30	40	50	100	0	10	20	30	40	50	100
1.	Freeness, ml CSF	150	182	173	164	155	150	250	150	190	185	165	155	150	250
2.	Drainage Time, Secs.	44	30	31	34	38	45	22	48	32	33	34	35	39	22
3.	Breaking Length, M	5360	6808	7330	6730	6110	4605	7405	5050	6735	6675	6990	5904	5362	8764
4.	Burst Factor	32.1	32.2	38.8	35.1	34 4	31.6	56 9	38.6	51.6	45.3	43.1	42 1	45.3	53.0
5.	Tear Factor	43.5	70.9	69.7	64.8	57.1	57.3	121	56.0	72 3	75.0	70.1	61.9	77 4	15.5
6.	Double Folds, MIT	55	83	112	84	77	37	874	134	323	407	376	455	316	160
7.	Sheet Density, g/cc	0.62	0.61	0.62	0.62	0.66	0.66	0.69	0.56	0.73	0.70	0.56	0.63	0.60	0.76

TABLE 9:—Probable Composition of "Mini Paper Plant Effluent"

Sr. No.	Particulars	Bleached
1.	pH	5.5—8.0
2.	Total Suspended Solids, PPM	1500—2500
3.	Total Dissolved Solids, PPM	800—1200
4.	BOD_5	500—1000
5.	COD	2000—4000
6.	Percent Sodium	Less than 60

will be cheaper to discharge the effluent into sea or river. In case of mini paper plants in populated centres, it will be advisable for the mill to reduce the effluent volume by reuse of white water, etc. consistent with process operations (without slime or picking problems) and paper quality.

Based on literature survey (11) and our own experience a paper plant making 20 tonnes/day bleached papers will probably have about 2 million gallons/day of effluent and its consumption will be as listed in Table 9. When the effluent BOD, for example, exceeds 500 PPM, the limit for use in irrigation (IST 3307-1965), the effluent can be treated in an anerobic lagoon having a detension capacity of 30 days at a BOD loading of 900 lbs/acre/day. The land requirement for this purpose will be around 20 acres. The BOD reduction will be 60–75%. The nutrient requirement will be based on a BOD:N:P as 100:2:0.5. Urea, ammonia phosphate and phosphoric acid may be used as the sources of nutrients.

Table 10A lists effluents good, medium or poor for irrigation purposes. Table 10B compares oxidation pond techniqute with anerobic lagoon method for effluent treatment. Where land (200 to 400 acres) is cheaply available, oxidation pond technique is preferably chosen for treating the effluent fit for irrigation. Depending on the type of soil, the land requirements for irrigation may

TABLE 10A:–Characteristics of Effluent for Irrigation

Sr.No.	Particulars		Good	Medium	Poor
1.	% Sodium		30	30-65	65
2.	Boron	PPM	0.5	0.5-2.5	2.5
3.	Chlorine	PPM	177	177-710	710
4.	Sulphate	PPM	480	480-960	960
5.	Total Dissolved Solids	PPM	1000	1000-3000	3000

TABLE 10 B:–Comparative Statment for Effluent Treatment by Aneorobic Lagoon and Oxidation Pond Techniques

Sr.No.	Particulars		Aneorobic Lagoon	Oxidation Pond
1.	Effluent Volume,	MGD	2	2
2.	Initial BOD_5	PPM	1000	1000
3.	Final BOD_5	PPM	400	400
4.	BOD Loading, lb/Acre/day		900	50
5.	Total Land Required, Acres		22	400
6.	Detention Time, Days		30	240
7.	Nutrient Requirements :			
	i) Nitrogen as N Kg/day		180	
	ii) Phosphorous as P, Kg/day		45	
8.	Disadvantages		High Nutrient cost	Dark Colour of effluent will prevent penetration.
9.	Advantages		Lessland requirements.	No running costs.

TABLE 11:–Land Requirements for Disposal of Effluent for Irrigation for 20 TPD Paper Plant

Sr No.	Particulars	Land Requirement (Acres)
1.	Sandy	40–50
2.	Sandy Loam	50–70
3.	Loam	70–100
4.	Clay Loam	100–200
5.	Clayey	200–340

vary (Table 11). The land may be owned by the mini plant or belong to farmers.

Most mini paper mill effluents, after oxidation pond or anerobic treatment, fall under the' good or medium' rating for irrigation purposes .The paper mill can profitably grow rice in the land irrigated by the effluent and the rice straw produced can be converted back into paper.

Conclusions

Mechano–chemical rice straw pulps are superior to pressure cooked pulps both in pulp yield and quality. The pulp yields are at least 5–6% higher in mechano-chemical cooking than in pressure cooking. The ash content in mechano-chemical pulps is around 3% as against 14% in pressure cooked pulps. The strength properties of the mechano-chemical pulps, especially the Double folds, are many times higher than those of pressure cooked pulps (25 vs 3 for unbleached pulps and 134 vs 24 for bleached pulps). At the same percent cooking chemical application, the pressure cooked pulps have lesser lignin content and higher opacity than those of mechano-chemical pulps. The black liquors from both the pressure and mechano-chemical cooks are low in total solids (5.4% and 2.8% respectively). Black liquor of mechano-chemical cook is rich in silica at 12.6% (on total solids) as against 3.4% silica (on total solids) in the case of black liquor of pressure cook.

CEH bleaching will do for rice straw pulps of around 75 GE brightness. Bleach consumption as chlorine will be around 7.5% on OD unbleached pulp. The same brightness can be attained in single stage hypo-bleaching too, but the bleach comsumption as chlorine will be around 14%. The strengths of single stage hypo bleached rice straw pulp are poorer, particularly in tear factor and double folds, than those of CEH bleached pulp.

Blends of unbleached and bleached rice straw pulps with the corresponding bamboo or Kenaf Kraft pulps have shown that medium strength Kraft paper and ordinary writing/printing papers can be manufactured from rice furnishes. About 60% rice straw pulp and 40% long fibered pulp will be good for medium strength Kraft pulps. Ordinary writing or printing papers can be made from 80% rice straw pulp and 20% long fibered pulp.

Where effluent treatment is necessary, the economical approach for a mini paper plant will be to render the effluent suitable for use in irrigating agricultural lands. Depending on the availability of land, oxidation pond (200-400 acres for 20 TPD mill) or anerobic lagoon (around 20 acres) techniques may be adopted for effluent treatment.

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