Writing and printing papers from rice straw

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SUMMARY

Rice Straw is an important raw materials used in a large number of small paper mills situated in paddy growing areas of our country. It is one of the best raw materials available in the country to manfacture writing & printing papers. Rice straw differs from many other raw materials and some special precautionary measures are necessary while designing mills for manufacture of fine papers from rice straw. An attempt is made here to highlight these measures.

Rice straw is to be given a different treatment in pulping because of its inherently different nature. Physically rice straw is rich in leafy portion and the seed containing spikes (rachises). Chemically it has a higher silica content and a low lignin content. Chemical recovery in rice straw based mills is yet to be a commercial success. Rice straw pulp has short fibers and has a relatively low initial freeness which leads to difficulty in washing but beating of the pulp is easy.

Wet cleaning of straw before pulping has been found to be a necessary step to achieve a good quality pulp. Pulping should be done under milder conditions with less chemical dosage and lower temperature. In this respect, the mechano-chemical pulping is found to be more promising for rice straw than the conventional pressure cooking system.

The Brown Stock is to be washed in either vacuum washers or Potcher washers depending upon the mill size and investment capability. Washing is difficult and hence larger washing area is required. Cleaning is done in Jonsson type screens followed by centrifugal screening and then centri-cleaning.

Bleaching can be done in either a single stage hypochlorite bleaching or a 3 stage CEH bleaching sequence depending upon the brightness requirement.

Refining of straw pulp has to be done very carefully giving a mild brushing action on the fibres.

Special care is needed in tne stock preparation to reduce the mottling effect while adding the dyes. Heavy slime formation is another problem faced in straw based mills which needs frequent cleaning of the system with slimicides. The stock approach flow system should have centricleaners and pressure screen with an arrangement to screen the pressure screen rejects before recycling it.

The problems faced on the paper machine are basically slow-drainage on the wire and fluff problem on the presses and driers. Possible solutions are discussed in the paper. It is necessary to add 20% to 30% long fibered pulp with the rice straw pulp to impart better strength property and smooth runnability on the machine. Retention aids are desirable to improve the retention on the wire which normally is lower for the rice straw pulp.

For effluent treatment in small paper mills, the most economic solution appears to be to use the effluent after segregation of black liquor and primary clarification for irrigation to raise certain selective crops.

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In India, there are about hundred and odd small paper mills using agricultural residues, waste papers, rags, gunny, jute waste as raw materials. A majority of them use rice and wheat straw. It is most unfortunate that we are still lagging behind in the small sector in making a good paper from these cereal straws so as to compete with the big bamboo based mills. Many modern mills in some of the developing countries like Egypt, Indonesia, Srilanka, Iraq, Syria and European countries like Greece, Rumania, Bulgaria, produce excellent quality papers with straw as a raw material in the furnish. The purpose of this article is to highlignt a few important steps necessarily to be taken in the manufacture of good quality papers from rice straw. In fact, because of its fibre morphology, it is more suited for fine papers rather than packaging papers provided good care is taken to get a cleaner and brighter pulp. Generally the problem associated in the manufacture of packaging papers from straw is the strength like burst, tear, tensile etc. which can be obtained only if long fibred pulp is blended with straw pulp to an extent of 40 to 50% whereas in the manufacture of writing and printing papers where strength is not so important as in the former case, long fibred content can be as low as 20%.

In our country, rice straw is being used by a large number of small paper mills situated in paddy growing areas, mainly in Gujarat, Maharastra, Andhra Pradesh, Karnataka and West Bengal, to manufacture corrugating medium, wrapping paper and writing papers. But these mills have to go a long way in making papers comparable to bigger mills using bamboo and hardwoods.

STRUCTURE OF RICE STRAW

Before discussing rice straw pulping, it is necessary to discuss few aspects of rice straw and its features which require special treatment in pulping.

The straw stems are erect, elastic and generally tubular structures separated at intervals by nodes, which occur as vascular bundles crowded together and interlaced to form a strong diaphragm between the internodes. The spikes or top portion of stem to which the seed is attached is generally found with rice straw. The leaf, starting at the node, forms a sheath partway up the stem and ends in a leaf blade.

The bast cells or fibres from the internodes form the major part of straw pulp. They are comparatively short and slender with sharp, pointed ends. Accompanying the bast fibres in straw pulp are the epidermal cells, the platelets, the serrated cells, and the spirals, all being small and relatively nonfibrous materials. They come mainly from the pith on inner part of the culm, from the nodes, from the sheaths, and from the chaffy portion of the straw. The composition of the various morphological portions depend mainly on the area where the crop is raised and the straw from which it is raised. Conventional crop is desirable for paper making since it contains more portion of internodes compared to the hybrid variety.

Chemical composition of rice straw as compared to wheat and bamboo is given in Table No. 1. It may be noted that in rice straw, the lignin content is low and ash content is high when compared to other raw materials.

TABLE NO. 1—PROXIMATE ANALYSIS OF VARIOUS RAW MATERIALS

	Wheat Straw	Rice Straw	Bamboo
Ash	7-8	13-15	3.0
Lignin (ash corrected)	16-18	11-18	26-28
Pentosans	26-30	19-20	15-16
Hot water solubles	10-15	13-14	4-5
Alcohol Benzene solubles	3-4	5-6	2 3
1% Sodium Hydroxide Solubles	41 45	43-44	22-23
Holocellulose (ash corrected)	67-70	55-57	60-62
Alpha Cellulose	39-40	35-36	40-42
Fibre Length, mm	1.5	1.3-1.5	2.7
Fibre width, Microns	15	9-10	15

Rice straw, although a cereal grain straw, is an exceptional material for paper making. Because of many special features, involved in its structure, rice straw is to be given a different treatment in pulping.

Presence of silica and appreciable amounts of entraneous materials, such as grain, husk, leaves etc. make rice straw not so desirable for making paper pulp. However, selection of rice straw as raw material for many of our small paper mills has many advantages to its credit, a major one being its perennial availability to the mills at lower cost being an annual crop, almost throughout the year except for a short period in off-season.

Most important is that selection of proper pulping technique can contribute significantly to the development of favourable characteristics in rice straw pulps for manufacture of good quality writing and printing papers.

Summarising, it may be mentioned here that rice straw differs from other raw materials in that it has a much higher silica and lower lignin content.

Physically speaking, rice straw contains much more leafy material than other straws. In pulping of rice straw, its silica content tends to decrease the strength properties unless care is taken to keep the ash content of the pulp low Recovery of chemicals and heat from rice straw black liquor is so far not a commercial success though plants have been installed at one or two places using huge capital investment. This is because of the high silica inherent in rice straw.

Rice straw pulp has a relatively low initial freeness which leads to difficulties in washing of pulp. Also in beating of rice straw pulp, care must be taken to prevent cutting action since it is already a short fibre.

STORAGE OF RICE STRAW :

Since the paddy crop is normally raised only for two seasons namely Kharif and Rabi, storage of straw for at least six months is necessary. Depending upon the lead, paddy is transported to the mill site either in bulk or bale form whichever is economic. Storage at mill site is done over a vast area in the form of stacks of pyramid shape. To protect from rain, normally the top layer is sloping on all the four sides covered with a closely knit layer of straw similar to the roof of a thatched hut. Care should be taken while building the stacks to see that the straw is air dry, as wet straw in the stacks can cause spontaneous combustion due to fermentation.

The storage area required for a 30 TPD mill is around 10-15 acres. The stacks are spaced properly to follow insurance regulations.

The straw can be reclaimed from the stacks during off season and conveyed to the raw material preparation section by tractor trailors or bullock carts or manually depending upon the lead distance.

Raw Material Preparation :

Rice straw is subjected to chopping and dedusting in this section. Straw chopping is not difficult, but most of the choppers do not give adequate capacity because of the bulkiness of straw. Straw has to be compacted before feeding into the choppers. Baled straw is helpful in this respect to some extent. Problem is more predominant if the mill receives straw in bulk form. This problem can be taken care of to some extent to making ropes of straw by twisting it at site before feeding to the choppers using more or less the same technique as is used in coir rope manufacture.

Wet Cleaning of Rice Straw :

As mentioned earlier, because of many undesirable material inherent in rice straw such as husk, spikes, chaf and the dirt sticking to it. a wet cleaning step is essential in case of rice straw which give following advantages :

1. Lower chemical consumption in cooking.
2. Better bulk density and hence higher production per digester.
3. Better quality pulp because of removal of undesirable material from the system.

Many modern mills outside India have adopted this system with good results. Some new mills in our country are also going in for this system. Till recently, the screw press required for squeezing the water from the straw was not available indigenously and had to be imported at high cost. Recently a few indigenous machinery manufacturers have started fabricating this item. Other equipments in this system namely, the hydrapulper, the dewatering drum and belt conveyors are already available from indigeneous sources.

The washed straw from screw press can be conveyed by belt conveyors to the digesters floor.

Buffer storage for wet straw can be done in false bottomed storage silos of small capacities for each digesters located above the digester floor. Extraction from the storage has to be through a chute directly into the mouth of the digester. Buffer storage is necessary to reduce the charging time into the digester.

Cooking :

In our country, most of the mills use batch pulping in globe digesters using soda process under pressure of 6 Kg/cm^2 for rice straw pulping since the mills are below 30 TPD capacity and continuous pulping for this capacity is not economical. Recently, some mills have adopted Mechano-chemical pulping process in Hydrapulpers at atmospheric pressure and 95°C temperature using caustic soda cooking chemical. This process has the following distinct advantages :

1. Cooking cycle is drastically reduced due to the short cooking time required because of rapid agitation to which the straw and chemicals are subjected to.
2. Caustic requirement for cooking is reduced.
3. There is an improvement in the pulp yield due to less degradation and less generation of fines as the straw is subjected to milder cooking conditions.
4. Pulp obtained has better strength.

5. Pulp has better beating characteristics and drains more rapidly.
6. Silica which is inherent in rice straw is more easily removed from the resulting pulp due to the lower temperature and rapidity of the cooking cycle. This phenomenon is a special feature of the Mechano chemical process which is totally absent in pressure cooking process.
7. Nodes, spikes, husk and grain inherent in the straw are more easily removed because the Mechano chemical treatment causes only swelling of these contaminants to facilitate their subsequent removal by rifflers and other pulp cleaning equipments.

However, in Mechano-chemical process, there are a few disadvantages. They are :

1. Higher power consumption.
2. Opacity of the paper made from this process is lower.

Though power consumption per ton of pulp is higher, it is only to an extent of around 20% and many advantages in Mechano-chemical process like lower consumption, higher yield, better strength properties and improvement in the quality of paper will more than offset this disadvantage.

Though the opacity in paper obtained from this pulp is lower than that obtained from pressure cooked pulp, it will be still same or slightly better than that obtained from bleached bamboo pulp. By increasing the loading material which is possible because of higher strength in pulp, opacity can be increased.

In other words, pressure cooked rice straw pulp gives paper having better bulk and opacity whereas Mechanochemical pulp gives papers with better formation and surface smoothness.

But the most versatile cooking system for rice straw is continuous cooking system of Pandia type. The main advantages of this system are :

— Maximum uniformity of pulp quality due to a thorough and continuous mixing of chemicals and steam with fibrous raw materials.

— Uniform steam and power requirements which reduces peak load demands in the steam and power plant.

— Low steam requirements because of low liquor solids ratio and continuous recovery of heat from blow tank.

— Uniform liquor demand:

— Potentially higher yields of equivalent pulp quality.

— Small space requirements.

— Lower labour cost because of greater productivity per man hour labour.

But inspite of these advantages. Pandia system has not become popular in India excepting in one or two mills. The main reason for this is the high capital cost involved, which is two to three times the cost of the conventional globe digesters for the same capacity. Moreover, most of the small mills based on agricultural residues are in the range of 15 to 30 TPD and for this operation, continuous system will not be economically viable.

Washing and Screening :

Pulp after cooking is stored in blow tank in case of pressure cooking or a stock chest in case of Mechanochemial process From here, it can be sent for washing. Either vacuum washers or Potcher washers can be used, depending upon the mill size and investment capability. If vacuum washers are used, only two stages are enough. The advantages of vacuum washers are that it brings down water consumption for washing and washing is more effective. Also the fibre losses through filtrate are less when compared to Potcher washing. However, for mill of smaller capacity (less than 15 TPD), Potcher washing will be enough.

The area required for washing straw pulp in vacuum washers is nearly three times that required for bamboo pulp because of its slow draining nature. Knotters are not to be installed before washing as its efficiency will drop tremendously. This is a deviation from the normal system used in bamboo or wood pulping systems.

In a system, where pulping is by pressure cooking process, it is necessary to process the cooked stock in a hydrapulper or through a deflaker-former one is more effective-before sending it to screening section. This is found to be an essential step in order to get better separation of the undesirable materials like spikes, nodes, husk etc in the subsequent cleaning operation. Also pulp obtained in this case is found to have better strength.

Cleaning section consists of Jonsson screen with 2-3 mm perforation followed first by centrifugal screen and then a battery of centricleaners Screening should have atleast two stages and centricleaners three stages, Pulp is then thickened preferably in open decker thickeners or vacuum deckers and stored in stock chests.

Bleaching :

For getting good brightness, a three stage CEH bleaching sequence is necessary though in smaller mills (15 TPD and below), a single stage hypochlorite bleaching can also be adopted. In single stage bleaching, brightness obtained can be at the range 69-70 °GE whereas in CEH system, brightness levels of 75 °GE and above can be achieved.

Now pulp is ready for stock preparation.

Stock Preparation :

The stock preparation in a straw based mill is very simple because of the fact that refining of the straw pulp is very easy. It takes very little horse power to refine the straw pulp since the initial slowness of the pulp in terms of °SR is high, being of the order of around 30 °SR For refining of straw pulp, disc refiners with disc patterns to do only brushing action are desirable. Many refiners of better design are in the market for straw type fibres. Refining is required only for the long fibred pulp like bamboo pulp, rag pulp etc which forms normally 20 to 30% of the furnish in a straw based mill.

Care is needed to see that addition of dyes is done carefully to avoid mottling. Being short fibred, straw pulp has more affinity towards dyes and hence unless good care is taken, paper may have mottling effect. Normally dyes after dissolving is diluted to 1% solution and added slowly into the stock chest using cloth filter. The agitation in the chest has to be thorough. To avoid mottling effect, dyes are added to the long fibred pulp and only after a thorough agitation for few minutes, straw pulp is taken into the chest. Addition of other chemicals like rosin, alum, etc. is done in the conventional way.

Being short fibred, retention on the wire for straw pulp is lower than other conventional fibres. Hence addition of retention aids while preparing the stock will help to improve the retention.

Heavy slime formation is another problem faced in straw based mills. Continuous addition of slimicides into the stock will control the slime to some extent. The stock chests should have good circulation and uneven surface or sharp corners inside the chest should be totally avoided. Bends in pipelines for stock and back water should be minimum.

Stock Approach System :

The stock approach system will have the consistency regulator, flow box, fan pump, centricleaners, pressure screen before the head box. Pressure screen is an essential item in the stock approach system without which the machine cannot be run in a straw based mill whereas in many conventional bamboo based mills pressure screens are sometimes not used. The rejects from the pressure screen can be screened through a flat screen or a Jonsson type screen to recover useful fibres which can again be recycled to the suction of the fan pump. The rejects from the flat screen/Jonsson screen can be rejected since it contains mostly undesirable particles like the husk, spikes and other foreign material.

Paper Machine :

Straw pulp is of slow draining nature and contains lot of fines which create fluff. The wire part, press part and dryers have to take care of these problems It is attempted to highlight a few points here to be essentially considered while designing the machine for rice straw pulp.

Wire Part :

Due to the slow drainage characteristics of rice straw pulp, the wire table has to be necessarily longer by at least 15-20% over that for bamboo or wood pulp. Many of the smaller mills in India based on agricultural residues have been operating second-hand machines imported from western countries. These machines unfortunately were designed for softwood pulps which behave differently on the machine. While installing these machines, it is necessary to increase the wire length to have a trouble-free operation for our conditions.

Another problem is that the wire should be so selected to have more retention. Also retention aids may be used to help in retention of fines as already mentioned above.

Wet suction boxes preceding the suction boxes will help in better and controlled drainage of pulp,

In order to have trouble-free operation of the web transfer from wire to first press, it is desirable to have suction pick up arrangement for speeds above 200 M/min.

It is necessary to blend straw pulp with at least 20% long fibred pulp to reinforce the straw at the wet end.

Fluff problem is too acute on the machine because of the fines in the straw pulp. The fines have a tendency to clog the fourdrinier wire unless high pressure oscillating showers are used to clean the wire. The fines are a source of trouble for the wet

felts also making it necessary to have an efficient felt cleaning system. The fluff sticks to the top rolls of the presses making the doctoring action extremely difficult. Fluff also accumulates on the drier surface reducing the heat transfer efficiency. Following measures are suggested to take care of the fluff problem :

1. Addition of good binders at the wet end.
2. Installation of lump breaker over the suction couch. This will help in compacting the paper web, thereby minimising the chances of fluff getting released in the press and drier sections. This will also help in reducing the moisture content of the paper web leaving the wire part. Paper breaks at the press section are also reduced, because of this.
3. The top rolls in the press section should be non-sticking type. No-pick roll or self skinning type roll has been found to be the most efficient followed by granite roll and microrock roll in the next order of preference.
4. The press rolls and drying cylinders should have efficient doctors preferably oscillating type at critical points (example first press roll).
5. The first press felt should be preferably synthetic or partly synthetic with needled construction.
6. Smoothening press after second press will also help to some extent to reduce the fluff problem.

Speed of the Machine :

It is necessary for small mills using agricultural residues pulp to have machines of speeds below 200 M/min since in this case, the operation becomes easier and sophistication needed for higher speeds can be done away with. One of the problems faced by small mills is the lack of adequately qualified and experienced operating and maintenance personnel to run the machines. Sophistication of the modern high speed machines is not desirable in small mills and hence the need to restrict the machine speeds to 200 M/min and suitably design the width of the machine for the required capacity which is not more than 30 to 40 tons per day.

Table No. 2 gives characteristic of paper made rice straw with a blend of around 25% long fibres.

TABLE NO. 2—TYPICAL TEST REPORT OF CREAM WOVE PAPER MADE FROM RICE STRAW

Substance		:	60 gsm
Bulk		:	1.5
Burst Factor		:	15
Tear Factor		:	45
Breaking Length	MD	:	3500
	CD	:	2200
Ash (%)		:	13

Converting Section :

The operation of rewinders and sheet cutters is same as other mills. But the problem mainly faced is that of fluff accumulating near the cutting tackles which needs frequent cleaning.

Fibre Recovery :

In small mills, fibre losses through the back waters are normally heavy because of the nature of raw materials used. It is necessary to recover the fibres from the back water system as much ae possible. First requirement of course in a machine head circuit is to make the system as much closed as possible. The fibres from excess back water have to be recovered in a save-all. Though there are different designs available, the Marx type Save-all which utilises gravity settling principle, is most desirable since the operating cost of this is very low compared to other Save-alls. The clarified back water from the Save-all can be recycled into pulp mill for waste paper slushing or final washing of straw pulp. It is also most important to keep a control on the fines in the head circuit which if built up in the system, tend to create runnability problem in the machine.

Recovery of Chemicals in Small Paper Mills :

Recovery of chemicals and heat from rice straw black liquor is so far not a commercial success though plants have been installed at one or two places using huge capital investment. The difficulty is mainly due to the very high silica content in the black liquor which is in the range of 6 to 8% on black liquor solids whereas it is 2.5—3.0% in case of bamboo black liquor.

A black liquor of this nature leads to excessive formation of scale in the evaporator with obvious undesirable consequences. It also poses problem in the smooth operation of the thick firing liquor and secondly because of the problem in the smooth flow of smelt. It also forms a slow settling sludge in the recausticising process.

In other words, till now a technically feasible and commercially viable solution has not been found for recovery of chemicals in a straw based mill. Till this is found, small mills will not be able to install recovery plants. Research projects in this field will have to be taken up in our country and institutions like the Central Pulp & Paper Research Institute at Dehra Dun can take the lead.

A feasible solution appears to be to eliminate silica from black liquor for which research work is in progress in a few places. At Rakta Paper Mills, Egypt, for example, pilot plant studies are still

under progress to remove silica from black liquor by flue gases. Commercial scale plants are still to be established. In our own country, at the Jogighopa unit of M/s. Ashoka Paper Mills, pilot plant studies have been carried out but so far no published data is available. At Thessalian Paper Mills, Greece also, similar work has been carried out.

Summarising, it can be mentioned here that there is an urgent need for carrying out an intensive research work on recovery of chemicals in straw based mills. Till a technically feasible and economically viable solution is found, small paper mills will have to carry on without recovery.

Effluent Treatment

Small mills do not have chemical recovery plant and as a result, the effluent will be containing more pollutants per ton of production compared to big mills. It has been found that the pollution load of a small paper mill of 30 TPD capacity without chemical recovery is equivalent to the pollution load contributed by an integrated 100 TPD mill with chemical recovery and both making bleached papers.

One important step necessary for small mills based on straw is to segregate the strong black liquor as much as possible from the brown stock before it is subjected to further washing. This alone will reduce the pollution load in the combined effluent by nearly 50%. This black liquor has to be stored in lagoons for disposal in a controlled way into surface water during monsoon. The remaining waste waters after primary clarification can be treated after nutrient addition in an activated sludge plant. The effluent after secondary clarifier will be fit for discharge into surface waters except for COD and colour. The sludge from the primary and secondary clarifiers will be dried on sand beds.

If large areas are available at cheaper rate, the mill can go in for aerated lagoon system in place of activated sludge system.

A cheaper and simpler method of treating the effluent is to use the effluent after segregation of black liquor and primary clarification for irrigation. Adjustment of pH and percent sodium by addition of Gypsum are necessary before using it for irrigation.

NEERI, Nagpur, has conducted extensive work on utilising the paper mill effluents for irrigation. Their findings reveal that these effluents can be successfully used for crop irrigation on coarse textured soils for growing salt tolerant crops like wheat, barley, maize, banana, sugar cane, kenaf, sesbania, etc.

In all these above mentioned treatment methods, an aneorobic lagoon before secondary treatment will help to reduce the power consumption in aeration or reduce BOD to make it suitable for irrigation. Larger the aneorobic lagoon, lesser will be the power consumption for aeration.

It may be concluded here that since the small paper mills will not have chemical recovery units, the pollution load in these mills is nearly three times higher than those mills with chemical recovery plants. Hence the most economic way of treating the effluent is to use it for crop irrigation after primary clarification and segregation of black liquor or anaerobic lagooning.

CONCLUSION :

Rice straw being available abundantly in paddy growing areas of our country, can be a very good source of raw material for small paper mills to manufacture writing and printing papers of reasonably good quality. Because of its different characteristics, physically and chemically, it is to be treated differently from other raw materials.

For getting a good end product, it is necessary to carry out wet cleaning of straw before the cooking process. Mechano chemical process with caustic soda has been found to be more promising for rice straw than the conventional pressure cooking process. Straw pulp washing is a difficult job needing more washing area. Coarse screening following by fine screening in centrifugal screens and finally centricleaning are the most essential steps in the pulp cleaning operation to be carried out after washing of the pulp.

Three stage CEH system of bleaching sequence is necessary to get straw pulp of good brightness.

Straw pulp refining is comparatively easier but care should be taken in stock preparation and stock flow appoach system to avoid colour mottling effect and slime growth. Addition of retentions aids is very much desirable to improve retention on the wire.

To take care of the slow drainage of the straw pulp, forming wire has to be longer. A few measures are necessary in the press section and dryers to reduce the fluff problem which is very acute in straw based mills. Machine should preferably be of slower speed.

Recovery of chemicals in a rice straw based mill is not yet a commercial success. Hence all efforts should be to reduce the chemical consumption in cooking of rice straw.

Effluent load from small paper mills is higher because of the absence of chemical recovery. It is

encessary to segregate the black liquor from the digesters and store it separately in lagoons for discharge only during monsoon. The other streams can be treated first for removal of suspended solids and then in anaerobic lagoons and finally after correction of pH and reducing sodium absorption ratio by gypsum addition can be used for irrigation of some selective crops. This way, the treatment cost can be brought down drastically.

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