Raw Material Preparation & Cooking For Agro-Based Paper Manufacturing

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ABSTRACT

Raw materials used for paper products vary widely, covering the entire spectrum from synthetic to natural fibers. The limitation of use for industrial applications of agro-based fibers has long been surpassed. Even though underrated as a potential fiber source, bagasse now draws more and more attention of the paper industry for making good quality of paper. Industries are using raw material as per their geographical location. As the climate conditions are different and the raw material is stored in open environment, it needs due care from the point source of storage. Raw material storage is an important issue for making good quality of paper as number of factors affects the quality of stored raw material. Special attention should be focused on the raw material storage & preparation. Dry de-pithing/ dedusting, storage and wet cleaning are the main factors for quality angle for bagasse, wheat straw, sarkanda and grasses. The treatment of these raw materials affects the consumption of chemicals in bleaching and parameters of final bleached pulp.

INTRODUCTION

The paper is manufactured from three major kind of raw material, i.e., wood, agriculture residues and recycled fiber. The total wood used in paper manufacturing is 5.8 million tones per year in India. Due to shrinking forest land, one has to search for the alternative sources of fiber. Agriculture residue and the recycled fiber offer a great opportunity to replace the wood fiber. In India, bagasse, wheat straw, rice straw, sarkanda and grasses are used in majority for paper manufacturing. Bagasse and wheat straw are commonly used in Northern region.

In present scenario, non-wood fibered pulp represents only 7% of the total world pulp production but at over 10 million tones per annum; it still represents a substantial quantity. About 70 % of this non-wood pulp production occurs in India and China where domestic wood fiber fails to sustain a continuous supply of fibers to pulp and paper industry. The estimated total availability of non-woody fibrous plant is 2300 million tones of which about 50 % are straws.

Another agro-based residue available in plenty is bagasse particularly in western U.P. In India total current production of sugar has touched a high figure of 9.95 million tones. The total cane crushed in this sector is estimated at 113.6 million tones. Therefore, bagasse produced in this sector is around 42 million tones. It is hoped that even if only 20 % of this quantity can be made available to Indian pulp and paper industry then there should be no difficulty in meeting the targeted demand of paper and board products.

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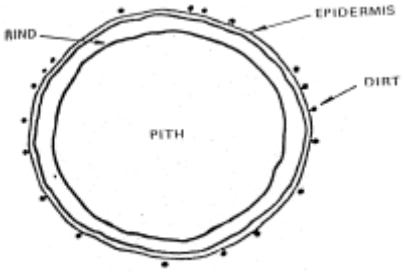
Morphology of bagasse fiber

Bagasse contains three main components fiber bundles, pith and epidermis. Each of these components behave differently during the pulping process. The fiber bundles contains almost 50% of the dry weight of bagasse. The fiber bundles in the rind layer of the stalk are oriented parallel to the axis of the stalk. The rind fiber is suitable raw materials for pulp and paper making. The central portion of the stalk is called the pith. It constitutes 30% of dry weight of bagasse. It consists of parenchyma cells which do not have characteristics of the fibers. The extreme outer layer of the stalk is a dense and thin layer of epidermis cells which are non-fibrous in nature. It is also resistant to pulping process, darker in colour than the pith and the fiber bundles. It is rich also with waxes and other impurities.

Typical bagasse constitutes 50% of the long & good fibers, 15% short fibers and vessels, 30% pith and 5% dense non-fibrous epidermis cells. In addition to these, bagasse also contains residual sugars, water soluble, dirt and colloidal soil, leafy materials and inorganics like silica and potassium. The non-fibrous materials are undesirable from pulping point of view as they consume more chemicals in pulping and bleaching and do not contribute to pulp strength.



Cross-section of sugarcane stalk

Fibers in bagasse consist mainly of cellulose, pentosans and lignin. Cellulose is a natural linear polymer and have specific gravity of 1.55. Cellulose is highly crystalline in nature. The ordered chains are tightly packed and have strong intermolecular hydrogen bonding because of the preponderance of hydroxyl groups. The cellulose is present in three types - α, β, and γ. The α-cellulose is known as pure cellulose, whereas β- and γ-cellulose combined are called hemicellulose. The hemicelluloses are chemically linked with cellulose molecules. The other main compound in sugar cane fiber bundles is lignin which is a high molecular weight substance. Because it is not possible to isolate lignin quantitatively from plant materials without chemical or mechanical degradation, its true molecular weight is not known. The amount of lignin that naturally occurs in sugar cane depends to a great extent on the variety and age of the cane. The amounts of sugar, lignin, and lignin-like compounds increase as the plant advances in age until the flowering time.

The bagasse is extracted from sugarcane through either pressing method or through diffusion process. The pressing method damages the fiber, however, in the diffusion method, the sugarcane is cut into small pieces,

mechanically disintegrated and then the sugar is extracted counter-currently with water in a diffuser. The bagasse so obtained is more uniform in size and pith can be removed by a screening process. Pulp from such bagasse have higher tear.

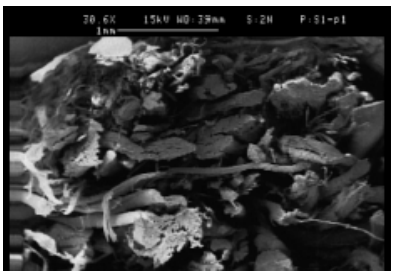


Fig: Scanning Electronic Microscope image of cross section of bagasse of fiber

Bagasse pulps are used for all grades of paper: writing & printing, toilet tissue, toweling, glassine, and others. Research has shown that some key factors should be considered in the production of bagasse paper. These relate to the use of a high content of chemical/mechanical action, highly efficient depithing systems, and storage method that assures excellent preservation of the bagasse properties, including color and brightness.

Raw Material Preparation & Preservation

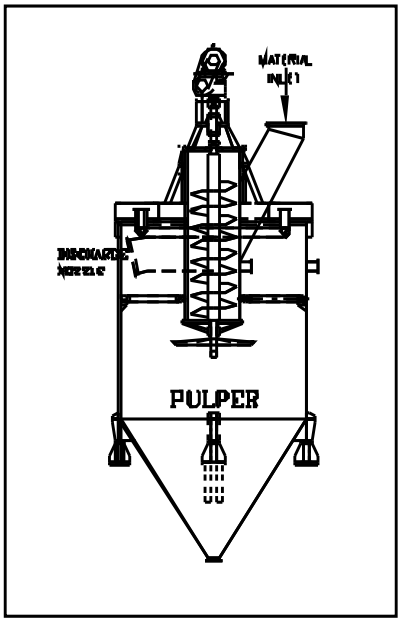
Sugarcane and wheat are the major crops in Western U.P. and in planes of Uttarakhand region and the generated bagasse from sugar mills and wheat straw from farmers' field is the major source of raw material for paper mills in this belt. The bagasse is available in loose as well as in bales form. The baled bagasse requires lesser space & contains lesser moisture and lesser decomposition problem. The baled bagasse can be stacked easily and there is no need of watering the stack. But over a period of time the bale's iron strings gets corroded and can not be separated completely during processing which create jamming problems in processing equipments. The loose bagasse can be used in two ways i.e., direct processing and processing through wet bulk storage. Direct processing means usage of bagasse in season within 10-12 days of its production otherwise cellulose fiber may hydrolyze under acidic conditions developed due to anaerobic fermentation. Wet bulk stored bagasse can be used in off-season. Only depithed bagasse should be taken in wet bulk storage otherwise it is not possible to separate out pith after wet bulk storage. If loose bagasse is not treated properly for off-season storage or not used within 10-12 days after production in season, the cooking and bleaching chemicals consumption will be on higher side with lower strength properties and viscosity.

On the other hand, wheat straw is available in loose form from nearby agriculture fields. The wheat straw requires storage in dry conditions with proper covering to prevent entry of water otherwise charring of fiber may occur. Therefore, it is very clear that the proper storage and preparation of agricultural-residue raw material is very important for getting good quality of pulp.

Basically, there are three methods for bagasse depithing-

- Dry Depithing
- Moist Depithing
- Wet Depithing

For the high quality papers, depithing is usually carried out in two stages dry or moist depithing followed by wet depithing. Dry depithing is carried out at a moisture level of 25% or less by means of modified hammer mills. Moist depithing is carried out at the moisture content of the bagasse as it is discharged from the sugar mills (about 50%). Moist depithing has a distinct economic advantage if performed at the sugar mill. Although pith has no value for paper making, pith at 50% moisture has economic value as fuel. Wet depithing is carried out with addition of water in a hydrapulper. Bagasse is discharged below the centre point hydrapulper with the help of intake chute and compressing screw. The compressing screw is rotated at a high speed to discharge the bagasse quickly inside the water. An impeller is equipped at the bottom of screw shaft where the bagasse is slushed vigorously to separate out pith from fiber. High pressure water is discharged through nozzles at the top of hydrapulper. Pith and other unwanted material is taken out from the bottom point of hydrapulper with the help of two numbers auto-control timer valves. The accepted bagasse slurry is taken out from the top shoot to aqua separator.



Filtrate of aqua separator and contaminated bottom discharge of hydrapulper is taken in B2 thickener via a refiller. The heavy materials are settled in refiller and filtrate from B2 thickner is taken in a clarifier. In clarifier the impurities like sand, pith etc. are settled down which is taken out from clarifier bottom and clarified water is taken for recirculation. The accepted bagasse recovered from B2 thickener is used again at the feeding point. The wet depithing/ wet washing is carried out at about 2.0-2.5% consistency inside the hydrapulper. The hydrapulper wet depithing system gives the maximum fiber cleanliness and removes the residual sugars and water solubles.

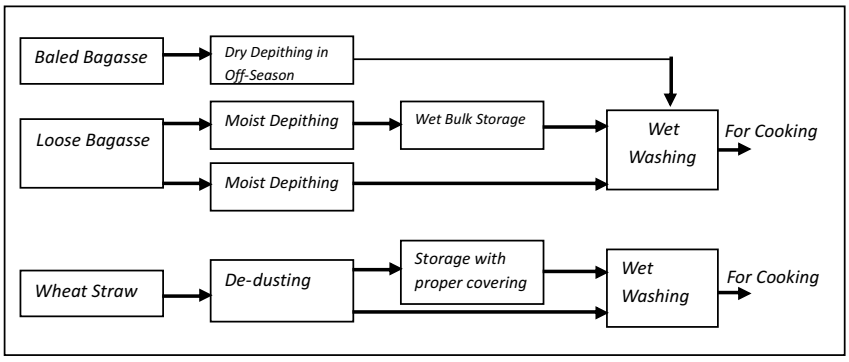


Fig.: Bagasse & Wheat Straw Storage and Preparation

De-pithing/ de-dusting of bagasse & wheat straw plays a pivotal role in pulp & paper manufacturing. Maintaining proper bath ratio, removal of good quantity of pith from bagasse and dust from wheat straw, and maintaining proper mixing ratio in case of mixed raw material is of equal importance. Better removal of pith and dust directly influence the quality of pulp.

In NTL, loose bagasse is stored after de-pithing in large heap and is continuously sprinkled with ETP treated wastewater for removal of sugar contents and to avoid acid generation. Acid generation in bagasse storage results in decomposition of fiber by which cooking, bleaching and even machine runnability gets affected.

Straw is defined as the stem or stalks of the certain cereals mainly wheat, rice, barley, oats and rye. Loose straw have lower bulk density and is very expensive to transport to the end users. The storage of the straw can be done in different ways. The most common are storage in open yard but it may result in charring of fiber if water penetrates the stack. To tackle this problem, there are a number of different ways for storage of straws

- Stack are built as high as possible and covered with a layer of sarkanda.
- Plastic covers are relatively cheap and can easily be placed on the top of the stack.
- Covered sheds of tin/ asbestos can also be used.

In dry dusting, wheat straw is processed through a deduster. Wet cleaning is carried out in the same hydrapulper as for bagasse at 2.5% consistency to separate out leaves and bristal powder, grains, hulls, silica, sand etc. De-dusting of wheat straw plays an important role in maintaining good quality of paper and properties of black liquor as higher silica & fines will leads to scaling during evaporation and firing in soda recovery.

We are using the treated wastewater from final outlet of effluent treatment plant for raw material washing and bagasse wet bulk storage and due to which the average fresh water consumption is only 64 m^3/ MT of paper production. The characteristics of treated wastewater are given as below pH= 7.2 -7.4; BOD_3 = 22-24 mg/l; COD = 215-235 mg/l; TSS = 80-90 mg/l; TDS = 1400-1800 mg/l; colour = slight brown.

Proximate analysis of Bagasse & Wheat Straw

Parameter	UOM	Bagasse	Wheat Straw
Cold Water Solubility	%	7.4	11
Hot Water Solubility	%	9.2	15.3
1% NaOH Solubility	%	42.2	41.8
α- Cellulose	%	45	42
Lignin	%	24.8	25.8
Acid insoluble Silica	%	1.8	7
Silica as SiO_2	%	0.7	3

The available bagasse & wheat straw are analyzed for their solubility in water & caustic and composition of cellulose, lignin & silica. The results are tabulated.

Continuous Cooking

Pulping methods include batch and continuous pulping process. There are different kinds of continuous pulping systems available, some of which can be used for special kind or group of raw materials and others have very wide application range. The advantages of the continuous pulping compared to the batch pulping is given as below

- Easier handling of bulky raw material
- Greater process flexibility due to quick response to changes in pulping variables
- More uniform pulp quality due to thorough and continuous mixing of chemicals and steam with raw material
- Avoidance of sudden surges in cooking-liquor requirements
- More uniform steam and power requirements
- Lower steam consumption due to low fiber-to-liquor ratio and efficient heat recovery from flash steam released at blow tank
- Higher black liquor concentration to the evaporating section of chemical recovery plant resulting better steam economy
- Increased pulp output
- Less manpower requirement
- Low building cost and less space requirement
- Gain in yield due to less rejection and degradation of pulp for the same kappa no.
- Better process control due to PLC/DCS controlled system.

Pandia type continuous digester - This system is in use in many mills and has proved very effective and versatile as pulping unit. A host of nonwood fibrous materials, such as bagasse, cereal straws, bamboo, reeds, and cornstalks are pulped by alkaline and neutral sulfite processes to produce a wide range of pulp grades.

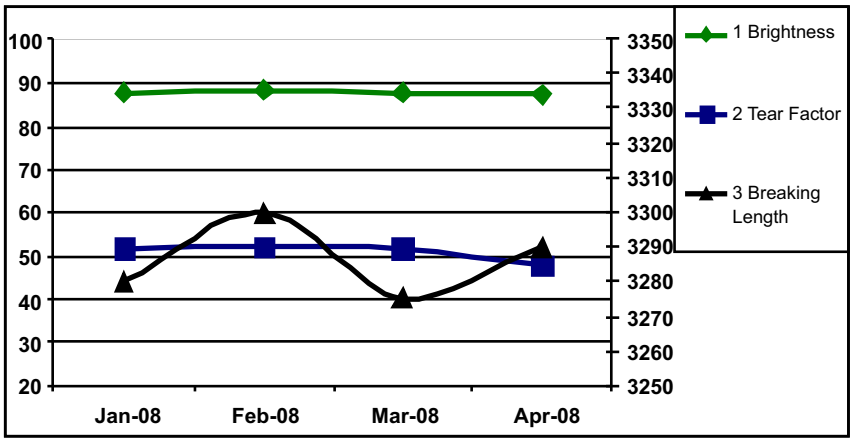
The Pandia continuous digestion system consists of a screw feeder and impregnation chamber, a pair of horizontal tubes fitted with screw conveyors joined by vertical connecting necks and a rotary discharger. The raw material is conveyed continuously either to mixer impregnator or alternatively directly to the chute of screw feeder by means of a suitable metering device. The incoming material is compressed through the

Average Raw Material Usage & Cooking Parameters

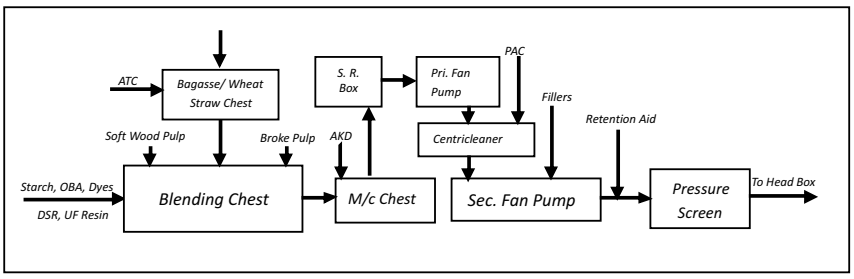
Sr. No.	Parameter		UOM	Jan.08	Feb.08	Mar.08	Apr.08
1	Raw Material	Bagasse	%	100	100	100	82.0
		Wheat Straw	%	-	-	-	18.0
2	Alkali as NaOH		%	12.97	12.97	13.04	13.4
3	Cooking Aid		%	0.05	0.05	0.05	0.05
4	Bath Ratio		-	3.2-3.5	3.2-3.5	3.2-3.5	3.2-3.5
5	Cooking Time		Min	20-22	20-22	20-22	20-22
6	Cooking Temp.		^{0}C	162-165	162-165	162-165	162-165
7	Kappa Number of Screened Pulp		No.	10.5-12.5	10.5-12.5	10.6-12.8	10.7-12.8

Average Strength Properties of Pulp

Sr. No	Parameter	UOM	Jan-08	Feb-08	Mar-08	Apr-08
1	Brightness	%	87.6	88.0	87.9	87.5
2	Tear Factor	-	51.8	52.0	51.8	47.8
3	Breaking Length	Mtrs.	3280	3300	3093	3281



Chemicals and fillers addition sequence



Average Consumption of Sizing Chemicals & Cost/T of Paper

Sr. No.	Parameter	UOM	Jan	Feb	Mar	Apr	Avg.	Cost
1	AKD Consumption	Kg/T	9.8	8.84	10.56	11.18	10.1	350
2	PAC Consumption	Kg/T	4.0	4.0	3.7	3.7	3.85	31
3	ATC	Kg/T	0.40	0.40	0.37	0.37	0.38	21
4	Retention Aid	Kg/T	0.40	0.42	0.33	0.34	0.40	131

screw feeder and the density of the mass is increased sufficiently to withstand the internal pressure of the digester. The plug is formed by the compacting effect of the screw feeder serves as a seal against any escape of the steam or blowbacks. The compressed mass loses its compactness as it comes into contact with the incoming cooking liquor and the steam at the reaction chamber before it drops into the first tube of the digestion Zone. Retention time within the horizontal tubes is regulated by controlling the speed of the internal screw conveyors. Pulping of the fibrous material continues due to intimate mixing of chemicals and steam as the raw material is conveyed through the horizontal tubes. The liquor to solids ratio can be maintained as low as 3:1 for satisfactory pulping operation. Injection of the black liquor at the orifice discharger facilitates uniform blow and thorough de-fibration of the cooked Pulp.

Diameter of the tubes and number of tubes are the major design criteria with respect to the pulping capacity of the Pandia digestion system. These two criteria and the variable drive arrangement for controlling the speed of the internal screw conveyors provide the necessary flexibility to control the retention time required for pulping various raw materials.

At NTL, Pandia type continuous digester (CD) is installed having pulp production capacity of 90 TPD. The digester is having two tubes with 1250 mm diameter and 10.75 mtrs. length between the centre of inlet & outlet of tubes. The cooking parameters like temperature, caustic dosing, cooking time and bath ratio can be changed at any time as per required quality of pulp. Cooking aid is used for reduction in caustic consumption and better strength properties of pulp.

The raw material usage and cooking parameters in Naini Tissues Limited are given in the table at left for the period January to April 2008.

Pulp from blow tank is processed through vibrating screen and then 4 - stage counter current washing. Uncooked pulp (reject) is separated out by vibrating screen. A refining, screening and cleaning unit is situated before final washing to clean and to make the pulp homogeneous.

Average Strength & Optical Properties of Naini Premium

Sr. No	Parameter		UOM	Jan.08	Feb.08	Mar.08	Apr.08
1	Brightness a value b value		%	90.8 3.51 -8.19	91.2 3.53 -8.16	90.5 3.50 -8.25	90.9 3.52 -8.25
2	Bulk		cc/gm	1.15-1.24	1.15-1.24	1.15-1.25	1.15-1.25
3	Smoothness		ml/min	150-200 200-280	150-200 200-280	150-200 200-280	150-200 200-280
4	Cobb		g/m^2	22 24	22 24	22 24	22 24
5	Tear Factor	MD CD	..	40.0 46.0	39.3 45.3	38.9 44.7	38.2 43.8
6	Breaking Length	MD CD	Mtrs.	4146 2117	4000 2090	3792 1980	3837 1972

Average Strength & Optical Properties of Naini Classic

Sr. No	Parameter		UOM	Jan.08	Mar.08	Apr.08
1	Brightness a value b value		%	95.5 3.44 -7.52	95.0 3.46 -7.62	94.5 3.48 -754
2	Bulk		cc/gm	1.24-1.30	1.24-1.30	1.24-1.30
3	Smoothness		ml/min	120-150 150-200	120-150 150-200	120-150 150-200
4	Cobb		g/m^2	23 25	23 25	22 24
5	Tear Factor	MD CD	..	43.5 50.9	43.9 50.3	41.3 47.5
6	Breaking Length	MD CD	Mtrs.	4236 2186	3857 1910	4232 2175

The washed and cleaned unbleached pulp is subjected through C-Ep-H-H bleaching sequence. The bleaching conditions like pH, temperature, retention time, chemical dosing are maintained in each stage of bleaching sequence. A screening and cleaning unit is situated before final washing stage. Washed and cleaned bleached pulp is collected in a storage tower and then supplied to stock preparation as per paper machine demand. The strength properties of bleached pulp is tabulated at left.

There is no significant effect on brightness of pulp even after mixing 20% wheat straw with bagasse in raw material during April 2008, however, the tear factor dropped considerably and very minor effect observed in breaking length of the pulp.

Approximately 6-7% long fiber as soft wood is used to support bagasse/ wheat straw pulp. Other additives like AKD with PAC, whitening agents, dyes, wet end additives and fillers are added here in the mixed pulp. Now this stock is ready for paper manufacturing. Stock is pumped to paper machine head box via machine chest and 4-stage centricleaners. Soft wood pulp and broke pulp are refined to maintain 40 45^0SR.

CONCLUSION

It is very clear that in case of agriculture residue paper manufacturing process, the raw material preservation and preparation is very important part. We have to give special attention on this area to avoid wear & tear of equipment, slow drainage on wire part, press picking and to reduce chemicals consumption in cooking & bleaching. Our results indicate that raw material treatment is very essential to maintain better strength & optical properties in the product and for smooth functioning of soda recovery.