Impact Of Wood Storage On Pulp And Paper Making Properties

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ABSTRACT

Significant changes take place in cellulosic raw materials during storage over a period of time. Study was conducted to quantify the impact of wood storage on wood decay, loss of moisture , chemical composition and paper making properties. Debarked eucalyptus wood was stacked for a period of one year in open atmosphere to simulate mill condition and wood samples were collected at two months interval. There was 5.3% loss in cellulosic biomass after one year storage of the wood due to different chemical and biological factors. Hemicelluloses and total extractives in wood decreased by 6.1 and 20.9% respectively; one percent sodium hydroxide solubility increased by 17.4% indicating modification in hemicelluloses and lignin chemistry. Unbleached pulp yield reduced by 1.5% due to decay in cellulose and hemicelluloses. Coarseness of the wood fibers reduced gradually from 57.7 to 42.9 g/m with the storage of wood for 12 months. Fiber with lower cellulosic mass required lower refining energy. Tensile index, tear index, burst index and double fold reduced substantially with the storage, from 54.7 to 48.1 Nm/g, 8.7 to 7.5 mNm^2/g, 4.2 to 3.7 kNm^2/g and 80 to 45 respectively.
Keywords: Debarked wood, storage, hemicelluloses, extractives, pulp yield, coarseness.

Introduction

Indian pulp and paper mills are using hardwoods (eucalyptus, poplar, subabul, casuarina and acacia), agro-residues (bagasse, wheat straw and rice straw) and grasses (bamboo and sarkanda) as source of fibrous raw material. To supply the raw material on sustainable basis mills store the raw materials for a considerable period of time extending to 12 months or more, depending upon harvesting or sourcing of particular fibrous raw material. Change in chemical constituents in the fibrous raw material takes place due to auto-oxidation with heat and ultraviolet light in presence of oxygen and moisture. Microbial decay of cellulosic material is the other factor for the change in chemistry of raw material (1). These factors combined together cause adverse impact on pulping and refining behaviour, morphological properties, and physical strength properties of pulp.

Storage of wood has some advantages as well as disadvantages for pulp and papermaking. Advantages include decrease in extractives and foam generation during washing operations. Storage of wood for 12 months lowers the extractives to 60 to 80% of the fresh value (2). Extractives decrease rapidly in initial period of storage specifically during first 60 days after harvesting (3). Reduction in extractives in the stored wood decreases the pitch problem in papermaking process (4). Pulp produced from stored wood requires less refining energy (5).

Disadvantages of wood storage include loss of biomass and pulp yield, and lower brightness and physical strength properties. Loss of biomass during storage depends on the climatic and storage conditions. 4-15% biomass deteriorates during storage (4, 6).

Present study was aimed at evaluating the impact of storage of debarked eucalyptus wood on loss of moisture, chemical constituents, fiber morphology and paper making properties.

Experimental

Experimental stack of debarked eucalyptus was prepared with seven rows of known weight of raw materials. After every 2 months one row was dismantled for the evaluation of raw materials and quality of pulp. Wood samples were chipped in the drum chipper and the chips were analyzed for moisture. Proximate analysis was carried out after grinding the chips in Wiley mill and screening on 40 mesh sieve.

Pulping was performed in autoclave digester consisting of six bombs of 2.5 l capacity maintaining the similar pulping conditions viz., time, temperature and bath ratio. Morphological properties of pulps were analysed with L&W fiber tester. Following analytical techniques were followed:

1% NaOH solubility: as per Tappi Test Method T 212 om-02

AB and total extractives: as per Tappi T 204 cm-07 & T 264 cm-97

Ash in wood: as per Tappi Test methods T 211 om-02

Brightness of the pulp: as per ISO 2470

Cellulose content: as per method (Updegroff, 1969)

DCM extractives: as per Tappi Test Method T 204 cm-97

Freeness of pulp: as per Tappi Test Method T 227 om-99

Gross calorific value: as per Tappi Test method T 684 om-02

Hand sheets of the pulp: as per Tappi Test Method T 205 sp-02

Hemicelluloses content: as per method (Deschatelets, 1986)

Hot water solubility: as per Tappi Test Method T 207 cm-08

Kappa no. of pulp: as per Tappi Test Method T 236 om-99

Klason lignin: as per Tappi Test Method T 222 om-85

Moisture content of wood: as per Tappi Test Method T 257 cm 02

Physical strength properties: as per Tappi Test Method T 220 sp-01

Refining of pulp: as per Tappi Test Method T 248 sp-00

Residual active alkali: as per Tappi Test method T 625 cm-85

Viscosity of the pulp: as per Tappi Test Method T 230 om-04

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Results And Discussion

Moisture and weight loss during storage

Moisture loss in the wood depends on weather condition. Wood released the moisture steadily from 19.3 to 7.1% at the end of 12 months period approximately at the rate of 1% per month (Figure 1). Sudden rise in moisture level at the end of 8th month was due to rainfall and moisture absorption by the wood. During stated storage period of 12 months the wood lost the bone dry quantity by an amount of 5.30% (Table 1). Initially upto 6 months the rate of biomass loss was higher i.e. @ 0.2-0.3% per month and subsequently it slowed down. Volatilization, auto-oxidation, microbial decay and their collective impact on the wood were significant at higher moisture level.

Change in chemical constituents

Hot water soluble components which included starches, tannins, gums, sugars, inorganic compounds, and coloring matter increased over the time from 3.24 to 5.0%. Some of the oligosaccharides present in the wood were converted to mono or disaccharides; the rate of their formation was predominant after 8th month. Hemicelluloses in wood decreased by 1.4% (from 23.0 to 21.6%) quite uniformly over the time at the rate of 0.12% per month (Figure 2). Proportion of poly, oligo and mono saccharides changed over the time due to the free radical formation by UV, atmospheric oxygen and degradation by bacteria, fungi etc. Decrease in cellulose content which is a combination of α, β and γ fractions indicated that along with lower molecular weight hemicelluloses low molecular weight fractions of cellulose (mostly γ cellulose) were formed over the time and part of them were lost as food to microorganism. The microbial activity may not be visible but its hidden activity was reflected by the decay of cellulosic and hemicellulosic fractions in the wood. Proportion of lignin in wood increased as both cellulose and hemicelluloses decreased. Difference in 1% NaOH solubility of stored wood for 12 months is 2.5% and hot water solubility in the same period was 1.76% (Table 2). This indicates the possibility of minor increase in lignin solubilization (0.74%) over the period due to the fungal conversion of lignin macro molecules to lower molecular weight fractions. Solvent-extractable substances in wood, which mainly contain fatty and resin acids, sterols, waxes and fats, non-volatile hydrocarbons and polyphenols decreased significantly over the period possibly through volatilization, auto-oxidation and free radical formation

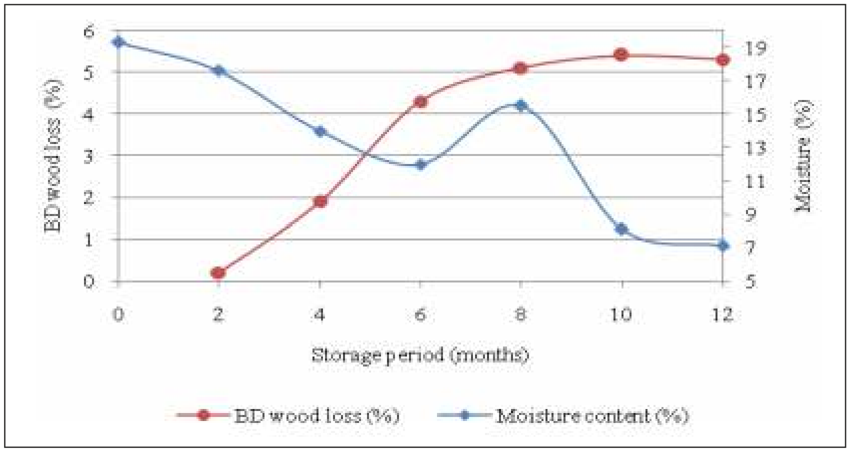

Figure 1: Effect of storage on loss of biomass and moisture

Table 1: Moisture and weight loss in debarked eucalyptus at different storage period

Parameter	Month					
	2nd	4th	6th	8th	10th	12th
Period of storage (month)	June-July	Aug-Sept	Oct-Nov	Dec-Jan	Feb-Mar	Apr-May
Average moisture at the time of de-stacking (%)	17.6	14.0	12.0	15.5	8.1	7.1
AD quantity loss in particular row (%)	5.6	11.8	12.9	13.5	14.1	13.6
BD quantity loss in particular row (%)	0.2	1.9	4.3	5.1	5.4	5.3

Average moisture at the time of stacking: 19.3%.

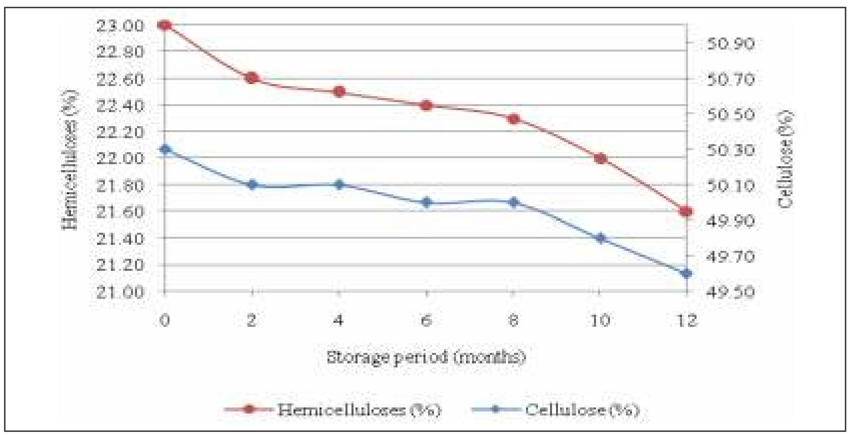

Figure 2: Effect of storage on cellulose and hemicelluloses

Table 2: Chemical properties of the debarked eucalyptus at different storage period

Parameter	Month						
	0	2nd	4th	6th	8th	10th	12th
Hot water solubility (%)	3.24	3.15	3.44	3.34	3.47	4.52	5.00
1% NaOH solubility (%)	14.65	14.86	14.93	15.45	15.70	16.00	17.20
DCM extractives (%)	0.53	0.47	0.44	0.43	0.40	0.39	0.38
A-B extractives (%)	1.19	1.09	0.95	0.90	0.90	0.88	0.86
Total extractives (%)	3.92	3.33	3.28	3.27	3.23	3.20	3.10
Cellulose (%)	50.3	50.1	50.1	50.0	50.0	49.8	49.6
Hemicelluloses (%)	23.0	22.6	22.5	22.4	22.3	22.0	21.6
Klason lignin (%)	27.2	27.5	27.6	27.6	27.8	28.2	28.8
Ash (%)	0.64	0.67	0.45	0.49	0.50	0.54	0.50

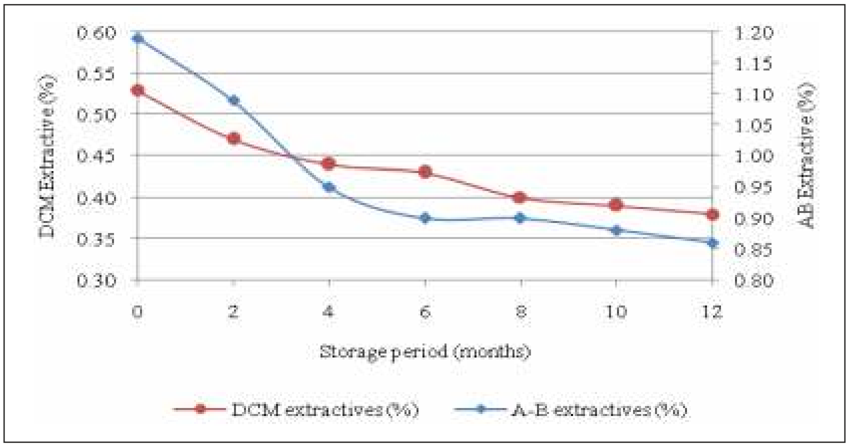

Figure 3: Effect of storage on extractives content

(Figure 3). There are some advantages with the lowering of extractive content like lowering of pitch and resinous compounds in pulp and less foam generation in washing process. But it compromised the intrinsic properties of the fiber which has been discussed in the following sections.

Pulping of debarked eucalyptus

Intrinsic change in cellulose, hemicelluloses and lignin structure and molecular size during the storage period was reflected through lower pulp yield, kappa number and pulp viscosity. The pulp yield, kappa number and pulp viscosity decreased by 1.5%, 0.7 and 0.4 cp respectively (Table 3). Increase in soluble components in 1% NaOH, and lowering of cellulose and hemicelluloses over the storage period were the factors responsible for the lower pulp yield. Lower free alkali in the black liquor also indicated the presence of acidic compounds formed during fungal decay of cellulosic/lignin components which consumed part of the active alkali. In spite of the higher solids and lower residual active alkali, the black liquor generated with stored wood showed lower calorific value. It indicated that more hemicelluloses, were dissolved in black liquor, which has relatively lower calorific value than lignin.

Morphological properties

The eucalyptus wood fiber did not undergo much change in its morphological properties during storage period but significant change in fiber coarseness was observed from the wood stored for 6 months from 57.7 to 48.7 g/m (Table 4). This value dropped further to 42.9 g/m during later part of the storage. Though the fiber length and width remained almost same for the entire period of storage, lowering of cellulosic mass in the fiber cell wall caused the gradual decrease in coarseness from 6th month onwards.

Refining of unbleached wood pulp

Unbleached pulp was refined in PFI mill at different freeness level (Figure 4) with 1200, 2450 and 4200 PFI revolutions to get targeted freeness of 550, 500 and 400 ml CSF (Table 5). It is observed that pulp produced from stored wood had lower freeness at the same refining level as compared to fresh wood. As discussed earlier storage of wood reduced the cellulosic material in the fibre cell wall which in turn consumed lower refining energy.

Table 3: Pulping response of debarked eucalyptus at different storage period

Parameter	Month						
	0	2nd	4th	6th	8th	10th	12th
Kappa no.	19.4	18.5	18.3	18.7	18.7	19.0	18.7
Reject (%)	nil	0.1	0.2	0.2	0.1	0.1	0.1
Yield (%)	47.9	47.5	47.5	47.3	47.3	47.0	46.4
Viscosity (cp)	14.7	14.6	14.6	14.3	14.4	14.5	14.3
Brightness (% ISO)	29.8	29.5	29.2	29	28.9	28.6	28.1
Black liquor properties							
Total solids (%)	21.2	21.1	21.2	21.2	21.4	21.4	21.7
RAA (g/l) at 20% solids	5.5	5.4	5.4	5.3	5.2	5.2	5.0
GCV (kcal/kg)	3239	3105	3118	3107	3171	3165	3052

Active alkali as Na_2O: 16.0%, cooking time: 165 min., sulphidity; 23.4%, cooking temp.: 160°C, bath ratio: 1:3.

Table 4: Morphological properties of unbleached pulp at different storage periods

Parameter	Month						
	0	2nd	4th	6th	8th	10th	12th
Average fiber length (mm)	0.616	0.605	0.611	0.614	0.642	0.640	0.638
Width (m)	15.2	15.1	15.1	15.2	15.8	15.7	15.6
Fiber shape, length wt'ed, (%)	92.7	92.8	93.3	93.7	91.4	91.7	92.0
Vessels per lacks fiber	230	212	226	229	248	304	246
Coarseness (g/m)	57.7	57.6	54.2	48.7	42.6	45.3	42.9
Mean kink angle	40.97	39.55	39.97	39.15	42.39	41.45	41.40
Number of kinks per fiber	0.26	0.26	0.23	0.18	0.34	0.32	0.30

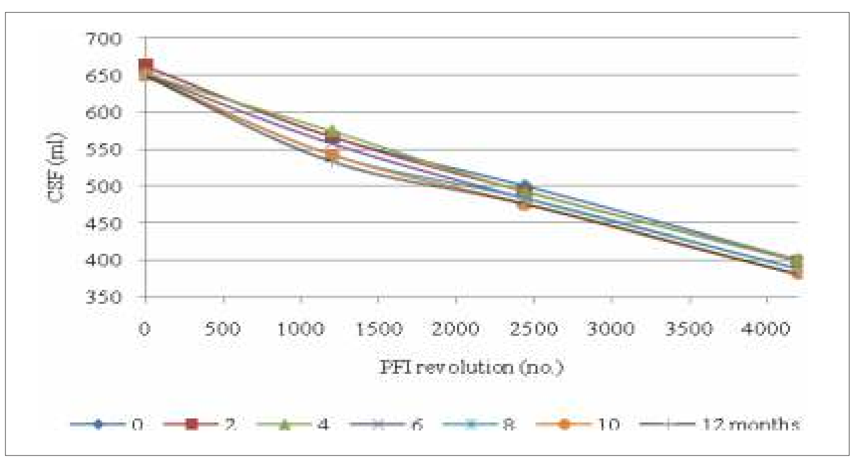

Figure 4: Effect of storage on refining

Table 5: Refining response of unbleached pulp

Parameter	Month						
	0	2nd	4th	6th	8th	10th	12th
Revolution (no.)	CSF (ml)						
0	662	662	651	651	650	650	650
1200	567	567	575	558	542	542	533
2450	500	492	492	483	483	475	475
4200	400	399	401	388	388	381	381

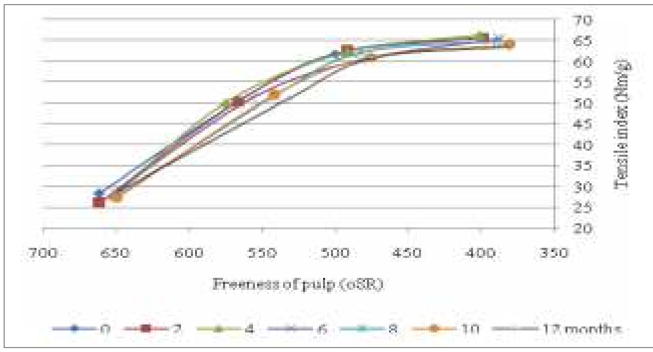

Figure 5: Effect of storage on tensile index

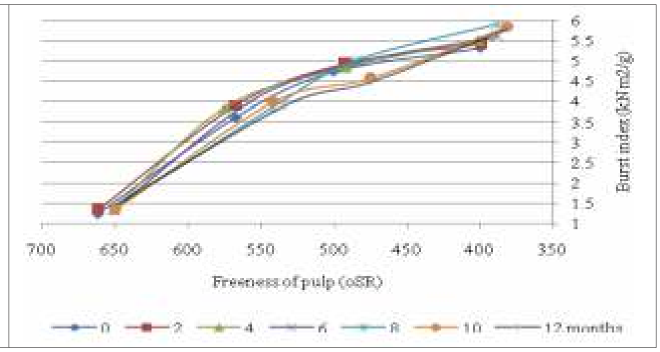

Figure 6: Effect of storage on burst index

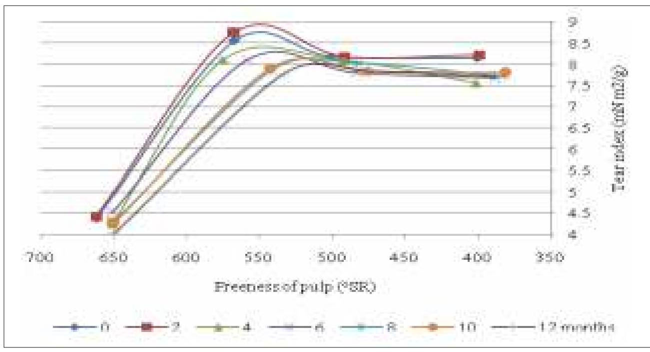

Figure 7: Effect of storage on tear index

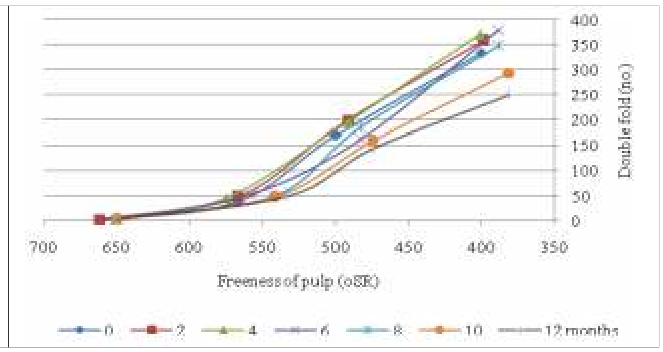

Figure 8: Effect of storage on double fold

Table 6: Physical strength properties of unbleached pulp at 550 ml CSF

Parameter	Month						
	0	2nd	4th	6th	8th	10th	12th
Bulk (cc/g)	1.45	1.44	1.46	1.43	1.47	1.47	1.40
Tensile index (Nm/g)	54.7	54.7	55.1	53.0	50.2	50.6	48.1
Burst index (kNm^2/g)	4.2	4.3	4.3	4.2	3.8	3.9	3.7
Tear index (mNm^2/g)	8.7	8.8	8.4	8.3	7.9	7.9	7.5
Double fold (no.)	80	90	95	75	50	50	45

Physical strength properties

Degradation of cellulosic material in the cell wall of fiber had impacted negatively on intrinsic property of the fiber which resulted in lower tear, tensile, burst index and double fold after 6th month of storage (Figure 5, 6, 7 and 8). Various physical strength properties were compared at 550 ml CSF, as at this freeness level unbleached pulp has maximum tear index. The values in the table reconcile the above observation on the drop of strength properties of wood beyond 6 months of storage (Table 6).

Conclusions

Debarked eucalyptus wood does not loose significant intrinsic fiber properties within six months of storage beyond which the decay of the raw material starts. Storage of wood over a period of twelve months has a significant impact on its constituents and biomass which decreased by 5.3%. Hemicelluloses and cellulose of the wood decreased by 1.4% and 0.7% respectively. Unbleached pulp yield of debarked eucalyptus reduced from 47.9 to 46.4% after storage of 12 months. Coarseness of the wood fibers reduced gradually from 57.7 to 42.9 g/m with the storage period due to loss of cellulosic mass in the cell wall. Tensile index, tear index, burst index and double fold reduced substantially with the storage, from 54.7 to 48.1 Nm/g, 8.7 to 7.5 mNm^2/g, 4.2 to 3.7 kNm^2/g and 80 to 45 respectively.

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