Study On Storage Losses And A New Method Of Raw Material Preservation For Some Common Hardwoods Used By Indian Paper Industry

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ABSTRACT

In order to keep the Indian Paper Industry rolling, the foremost thing which must be kept in mind is the availability of the raw materials. The use of wood based raw material fulfills ~40 % of total raw material demand. Indian wood based pulp mills are using MHW (mix hardwoods) along with bamboo. The most common hardwoods used by these mills are eucalyptus, acacia, casuarinas, subabul etc. For a consistent supply of raw material, mill store the wood logs for different periods ranging from 3-12 months or even more. Storage of freshly cut wood for short term (3-4 months) is good for processing during pulp and paper making.

Considering the biodegradable nature of the fibrous raw materials and its high vulnerability to such degradation during storage, conservation of pulpwood is of utmost importance. The impact of wood degradation during storage not only confines to pulp yield but also affect the pulp strength. On account of difficult condition of harvesting, bottlenecks in transportation and inadequate protection at depots/ yards coupled with tropical climate of the country, as much as 10% of the material is estimated to be lost. Such losses may be as high as 30-40% in more degradable material like bamboos and agrobased raw materials.

In order to prevent the raw material degradation, mills apply organophosphates and organochlorine pesticides like biltox, pyrophos etc.. It helps in minimizing the deterioration of wood to some extant. The toxic nature of pesticides is potential health hazard and their use in paper mill is a question.

In the present communication a detailed study on effect of storage of subabul, casuarina and eucalyptus, has been carried out. The first part of paper has covered the impact of storage on chemical composition, pulp quality and physical strength properties of these three raw materials. While the second part has detailed laboratory study on an environment friendly product as fungicide for preservation of wood.

Introduction

Cellulosic fibrous raw materials are normally stored in the forest depots and mill yards sometimes up to a period of one year. During such storage process, most of the paper mills have observed that these raw materials are susceptible to natural bio-degradation, fungal and insect attack. (1-5)

The storage of wood with high moisture content is more susceptible to deterioration particularly in warm climate, in comparison to air dried wood. The combination of moisture along with fungal attack gives all favorable conditions to wood deterioration. Storage of wood affects on specific gravity, wood composition, pulp yield and strength properties. (5-7)

Even at a conservative estimate of 10% storage loss in fibrous raw materials, amounts to 0.35 million tons of wood/ bamboo per annum for Indian Paper Industry. It results in 0.15 million tones of finished paper. Financial losses in terms of raw material due to these effects are to the tune of Rs.700 million annually. Hence, it is imperative to follow certain techno-economically-feasible practices to reduce these enormous losses. Besides minor loss of raw material leads to increased cost of fibrous raw materials and proportional deforestation.

Decayed wood consumes more alkali. Pulps from decayed wood show generally lower yield and lower strength properties except for their tensile strength. Extractives in woods are substantially reduced after storage of wood in open climate.(8,9).

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Microorganisms involved in the degradation of lignocellulosic materials

Wood and other lignocellulosic materials are degraded by a variety of fungi and bacteria. Most of the fungi

Category of Fungi	Name of Fungi
Soft Rot Fungi	Aspergillus niger
	Chaetomium cellulolytium
	Fusarium oxysporum
	Neurospora crassa
	Penicillium pinophilum
	Trichoderma reesei
Brown Rot Fungi	Coniophora puteana
	Lanzites trabeum
	Poria placenta
	Tyromces palustris
White Rot Fungi	Phanerochaete chrysosoporium
	Sporotrichum thermophile
	Coriolus versicolor

able to produce the necessary fungis for the degradation of lignocellulosic materials. Fungi living on dead wood that preferentially degrade one or more of the wood components cause three types of wood rot, i.e., soft rot, brown rot and white rot. The list of most commonly found fungi is given on back page (10-12).

Preservation of wood

The wood stored at mill yard is preserved from deterioration by fungi and borers. Paper mills apply biltox, pyrophos etc. for preservation of wood. These chemicals are toxic in nature, and can be health hazard. These have not reached significant commercial use because in addition to economic factors, environmental considerations limit what can be applied. It must be assumed that whatever chemical is applied to storage of wood logs, will eventually in some amount be extracted from the piles by rainfall and can make its way into the ground water supply unless proper precaution are taken. Hence toxicity question must be answered before wood preserving chemicals are widely used. The sulphur based fungicides are used for plant for control of fungal growth. These are basically organic sulphur compound and commercially available by trade name zineb, ziram etc.

The washings of lime contains weak green liquor and does not have further use in mill. The sulphur present as sodium sulphide can be apply on wood logs for preventing the fungal attack. This is also earlier reported that sodium sulphide can be applied as wood preservative.

In order to understand the changes in raw material during storage a study is required on raw material composition, pulping and papermaking properties. At CPPRI a detailed study was carried out on effect of storage of various raw materials viz eucalyptus, subabul and casuarina on pulp quality. In the first part of paper the findings on chemical analysis, pulp characteristics and paper making properties are being discussed, while second part has detailed about the study on laboratory scale findings of effect of sodium sulphide on wood preservation.

Chemical composition of the fibrous raw materials & their significance

Studies on chemical composition of wood is an important parameter for the preliminary characterization of cellulosic raw material & its potentiality for pulp & paper making. It gives an assessment of fibrous (cellulose) and non fibrous (lignin, hemi-celluloses, extractives and inorganic contents) materials. Importance of these components is relevant to the studies of fibrous raw material for the storage.

A. Ash

Ash content of any fibrous raw material signifies the amount of inorganics like silica, calcium and magnesium etc. present in wood. The ash content of the fibrous raw materials indicates the presence of inorganic in the range of 0.5 to 1.0% in softwoods and hardwoods. The inorganic quantity varies from 1.0 to 2.5% in bamboo and bagasse, 5.0 to 10.0% in wheat straw and other grasses and more than 15.0% in rice straw.Literature review indicates that lignocellulosic material degrades during storage but ash content which has inorganics, increased with storage period.

B. Water Solubility (Hot Water & Cold Water Solubility)

The water soluble of wood include gum, low molecular weight phenolics, pactines, low molecular weight polysaccharides and other polar extractives such as free amino acids and alkaloids etc. It gives an idea about the anticipated pulp yield in case of mechanical pulp. When the fibrous raw material is subjected to storage, these components decrease with the storage period. The Decrease in water solubles is an indication of deterioration of the raw material. The reason is that when fibrous raw material is decomposed due to the attack of fungus the deteriorated components increase the water solubility.

C. Alcohol Benzene Solubility (Extractives)

Some woods contain essential oils, resin acids and sterols whereas others yield tannins and coloring matter. The color, odor, taste or unusual flammability can be attributed to extractives. They may interfere with the pulping process, cause foaming and sometimes cause corrosion. Juvenile wood contains higher extractives than matured one. During the storage alcohol benzene solubility decreases as some of the organic substances like essential oils (present in eucalyptus, pine etc.) get evaporated. It is good to store the freshly harvested raw materials for a period of two to three months in order to decrease the extractives.

D. N/10 NaOH Solubility

N/10 alkali solubility perhaps the single most important parameter which gives idea about the physico-chemical nature of raw material. It also dissolves out all wood components extractable by means of hot water. In addition to water soluble, it also dissolves almost all the polar components in wood via their sodium salt formation. A fraction of lignin, hemicelluloses and low molecular weight cellulose are also extractable with sodium hydroxide. Sodium hydroxide solubility could be used as a diagnostic parameter to assess the microbial decomposition /degradation of a particular raw material and also to asses the comparative chemical pulp yield of raw material, to be obtained.

E. Lignin

Klason lignin is an indication of acid insoluble lignin present in wood. More or less it represents the quantitative amount of lignin in wood as the amount of acid soluble lignin is comparatively almost negligible.

F. Holocellulose

Holocellulose is the major component of wood cell wall (60-80%) and represent the cellulose and hemicelluloses. Isolation of holocellulose without its partial degradation is very difficult, if not impossible.

Physico chemical studies of holocellulose gives an idea about quality & quantity of paper to be produced. Holocellulose is a collective name referred to cellulose and hemicelluloses. Cellulose molecule containing well ordered glucose molecule is known as alpha cellulose having Degree of Polymerization (D.P.) 600-2000 while beta and gama cellulose have D.P. around 400-600 and 25-400 respectively.

Alpha cellulose is insoluble even in 17.5% NaOH while beta and gamma cellulose are soluble and go into solution phase. Cellulose and hemicelluloses can be precipitated out by absolute alcohol. Hemicelluloses are low molecular weight (lower D.P. 100-250) polysaccharides. From pulp and paper making point of view the analysis of holocellulose, alpha cellulose and hemi-celluloses is of great importance. As raw materials are stored in open climate, the reduction in alkali and water solubilities affects on total mass of the wood. This results in increment

Ttable 1 : Proximate chemical analysis of subabul, casuarina and eucalyptus

S.No	Parameter	Subabul		Casuarina		Eucalyptus	
		0 month	9 month	0 month	9 month	0 month	9 month
1.	Ash content, %	1.05	1.05	1.05	0.80	0.84	0.58
2.	Cold water solubility, %	2.46	2.75	1.67	1.40	0.33	1.26
3.	Hot water solubility, %	3.1	3.65	2.53	2.00	5.80	2.10
4.	Alkali solubility N/10, %	14.09	16.30	12.23	14.88	14.48	15.20
5.	Total lignin content, %	26.76	24.00	26.1	23.02	29.14	26.11
6.	Pentosan content, %	17.92	15.78	17.0	15.77	15.31	12.94
7.	Holocellulose content, %	77.27	77.66	76.0	78.0	75.80	77.26
8.	Alcohol benzene solubility, %	1.93	2.66	1.52	0.82	1.83	1.30

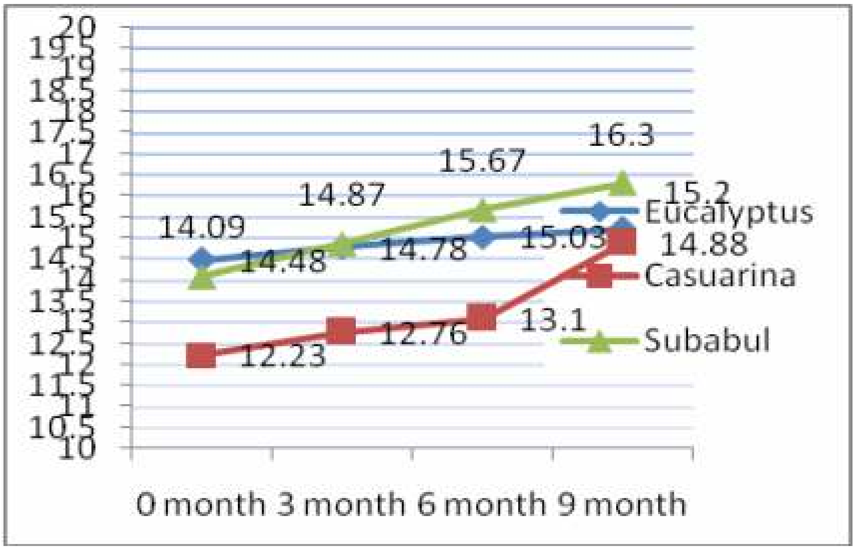

Fig. 1 Effect of Storage on N/10 alkali solubilities

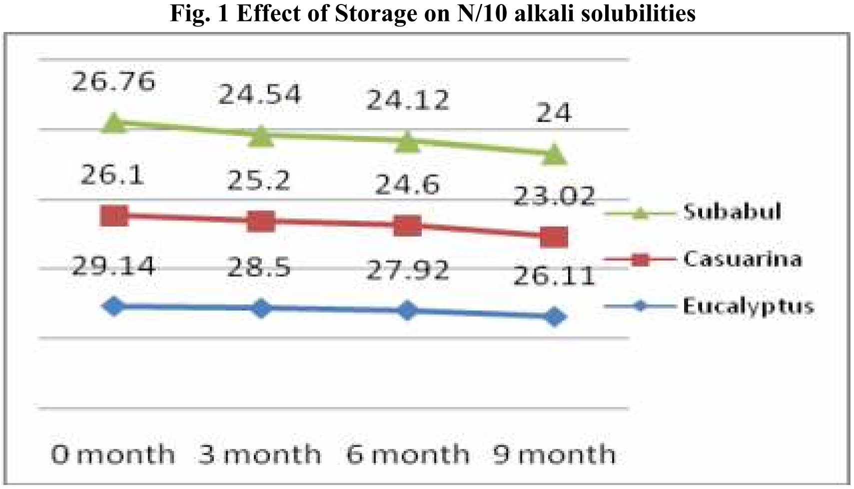

Fig 2. Effect of storage on lignin content

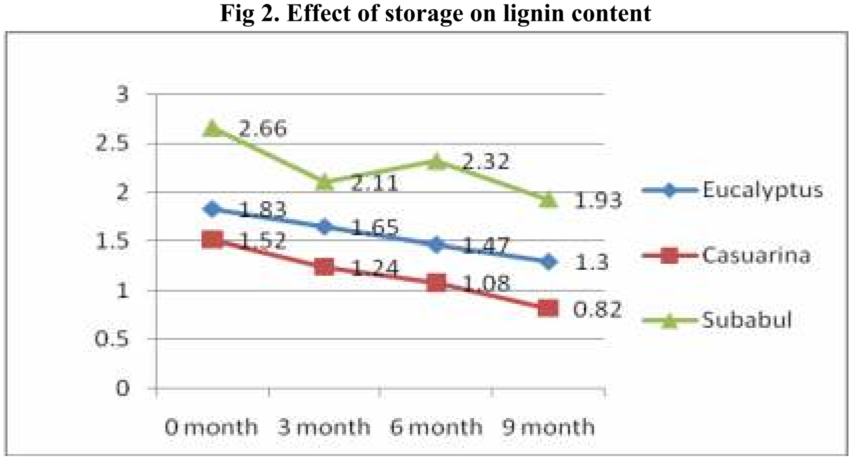

Fig 3. Effect of storage on Alcohal benzene solubilities

of holocellulose content.

G. Pentosans

Pentosans are the polysaccharides, mainly built up from pentosan sugar units (principally xylose and arabinose). These get hydrolysed and converted to furfural with strong hydrochloric acid. Pentosan content gives an idea about the amount and nature of hemicelluloses, particularly hemicelluloses having pentosan as building unit, present in wood. During storage hemicelluloses are degraded to some extent due to degradation of low molecular weight short chain pentose sugars

Experimental

Raw material Storage and collection

Raw material was stored at mill site under the mill conditions and collected quarterly. Wood logs were chipped at mill site and prepared for proximate chemical analysis and pulping experiments.

Pulping Experiments:

Chips collected after storage period of zero, three, six & nine months were cooked in laboratory series digester under mill conditions cited below. Pulping experiments were carried out in laboratory series digester with the objective to obtain desired unbleached kappa number The identical cooking conditions were maintained through out the studies. Unbleached pulp was characterized for Kappa number, yield, rejects, brightness and viscosity as per the standard methods.

Cooking Conditions

Cooking time	:	90 min.
Ambient to 100 °C	:	30 min.
100 °C to 165 °C	:	90 min.
At 165 °C	:	90 min.

Result And Discussion:

1. Chemical Analysis of Stored Hardwood Samples

The results of proximate chemical analysis of subabul, casuarinas and eucalyptus at starting and after 9 months are shown in table 1and fig 1,2 & 3.

1. Results of Pulping During Storage of Hardwoods

The results of Pulping experiments are given in table 2 and fig 4 &5

1. Physical Strength Properties of unbleached pulps of

Ttable 2 : Pulping of subabul, casuarina and eucalyptus

S.No.	Parameter	Subabul		Casuarina		Eucalyptus	
		0 month	9 month	0 months	9 months	0 months	9 months
1.	Na_2O added, %	21	21	19	19	19	19
2.	Sulphidity.%	20.0	20.0	20.0	20.0	20.0	20.0
3.	Bath ratio	1:3.5	1:3.5	1:3.5	1:3.5	1:3.5	1:3.5
4.	Unscreened pulp yield %	48.1	47.0	48.2	46.9	45.5	45.0
5.	Screen rejects, %	0.78	0.10	0.53	0.62	0.18	0.40
6.	Kappa number	17.0	14.5	19.0	20.2	16.0	15.2
7.	Brightness, % (ISO)	27.2	25.1	30.5	25.8	28.5	25.6
8.	Unbleached pulp viscosity cm3/g	743	690	679	852	662	687

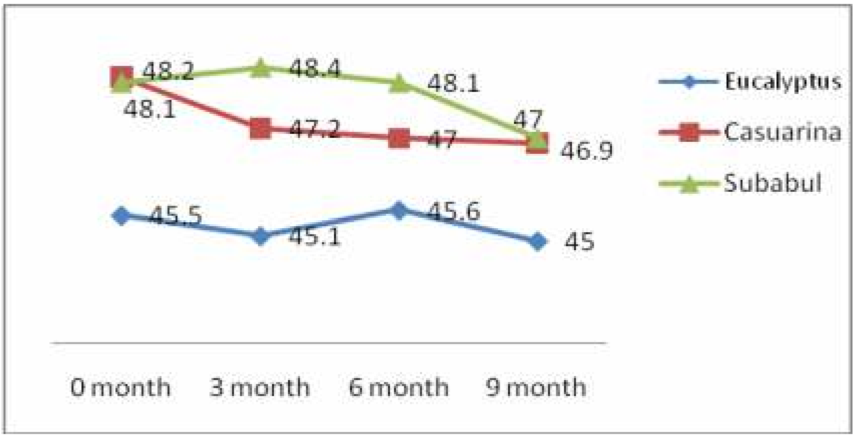

Fig.4 Effect of storage on pulp yield

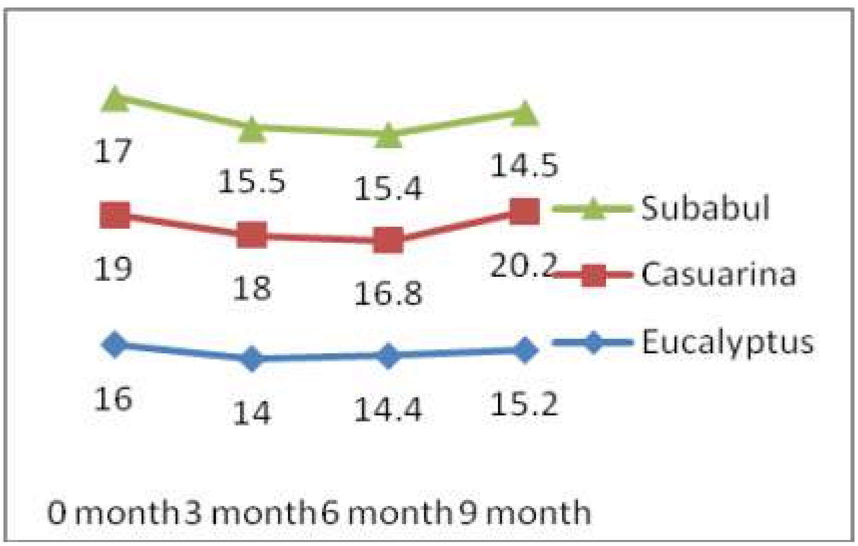

Fig. 5 Effect of storage on pulp kappa number

Table 3: Physical Strength Properties of unbleached pulps of subabul, casuarina and eucalyptus

Parameters	PFI(rev)	Freeness, ml, CSF	Apparent Density /cm3	Burst IndexKPam^2/g	TensileIndexNm/g	Fold Kohler Molin (log)	Tear Index mNm^2/g	Porosity Bendsen(ml/min.)
0 month (subabul)	4000	295	0.86	5.0	73.0	2.90	6.50	86
9 month (subabul)	3000	300	0.82	5.20	79.0	2.33	4.60	115
0 month (casuarinas)	4000	320	0.75	4.40	71.0	2.20	6.90	497
9 month (Casuarina)	5000	320	0.75	5.00	75.0	2.32	7.75	375
0 month (Eucalyptus)	4000	295	0.77	4.65	78.0	2.54	6.90	293
9 month (Eucalyptus)	5000	350	0.70	5.90	80.0	2.32	7.50	595

subabul, casuarinas and eucalyptus

The results of physical strength properties (at 300 ml freeness) of unbleached pulps of subabul, casuarinas and eucalyptus pulp of initial and 9 months old wood samples are given in table 3

Storage of Subabul

- Results shown in Table 1and fig 1-3 revealed that with storage period N/10 alkali solubility increased from 14.09% (zero month) to 16.30% (nine month). An overall increase of 2.21% occurred after nine month storage of Subabul which indicated degradation on storage. Only marginal improvement in hot water solubility was observed (less than 1.0% corresponding to 0.55%)
- An appreciable drop of 2.76% in lignin content after 3rd quarter of storage (after nine month) was observed. Out of total 2.76% drop 80.43% occurred after first quarter of storage. Later on it dropped drastically form 80.43% to 15.22% in second quarter followed by 4.34% in the third quarter out of the total drop of 2.76%.
- Degradation of low molecular weight carbohydrates with storage period was evident from reduction in Pentosan content. Increase in alkali solubility also supported the degradation of low molecular weight carbohydrates. Maximum reduction in Pentosan content occurred during the last quarter of storage corresponding to 44.99% of total reduction of 2.14% after storage of nine month.
- Contrary to the above, marginal increase in holocellulose content from 77.2% (zero period storage) to 77.66 after 9 month storage was revealed. The increase in holocellulose content may be assumed due to decrease in total mass of the wood besides higher rate of assimilation of carbohydrates than degradation rate during storage.
- The unbleached pulp yield decreased 48.1 % to 47.0% after nine month which indicated decay of subabul wood during the storage period of nine month. Drop in unbleached pulp viscosity from 743cc/gm to 690cc/gm after nine month also supported the degradation during storage.
- Adverse effect of storage period was not observed on physical

strength properties of Subaul except tear index which dropped from 6.50 mNm^2/gm (zero period) to 4.60 mNm^2/gm after 9 month.

Storage of Casuarina

- Table 1 indicated that alkali solubility in case of Casuarina increased from 12.23% to 14.88 % after storage period of nine months.. An overall increase of 2.65% occurred during nine month storage with maximum increase of 67.17% of total observed during the last quarter.
- An appreciable drop of 3.08% in lignin content was evident after nine months of storage.
- Pentosan content also dropped over a period of nine month storage. An over all drop of 1.23% was observed after third quarter of storage.
- Like Subabul, in case of Casuarina also holocellulose content improved marginally from 76.0 to 78.0 after nine month storage period . The increase in holocellulose content may be attributed to decrease in total mass of wood on storage and higher rate of assimilation (polymerization) than degradation (depolymerisation) of carbohydrates. Table 1.
- The unbleached pulp yield decreased by 1.3% over a period of nine months (tabl 2, fig5).

Storage of Eucalyptus

- Results summarized in Table 1 indicated that only marginal improvement in N/10 alkali solubility occurred during nine month storage of Eucalyptus. Less than 1.0% increase was observed (only 0.72%).
- Maximum drop in lignin content occurred during the last quarter of storage with a corresponding value of 59.74% of the total drop i.e 3.03% (after nine month storage). Remaining 40.26% occurred during first six month of storage period.
- Pentosan content varied from 15.31% to 12.94% with an overall drop of 2.37% after nine months of storage.
- Only marginal drop of 0.5% in unbleached pulp was observed after third quarter of storage. Any appreciable impact of storage on physical strength properties (table 3) of Eucalyptus was evident.

Preservation of wood (Eucalyptus) using weak green liquor washings (GLW)

In order to stop the decaying of wood during storage, mills are applying pesticides/fungicides. Paper mills which are preserving wood during storage use phosphorus based pesticides/ fungicides. These chemicals are very toxic in nature and can be harmful when after washings of logs effluent rich with these chemicals mix with effluent of other streams. Their harmful effect is much serious due to the persistent nature of these chemicals. Central Pulp and Paper Research Institute, worked on a novel method of preservation of wood during storage. In the present study which is carried out on eucalyptus chips, green liquor washing (GLW) is applied as wood preservattive. GLW with lower concentration of sodium sulphide is rich in sulphur which helps to prevent the growth of fungus. The favorable conditions are maintained to grow fungus on eucalyptus chips by keeping proper moisture and nutrient level. One part of this is spiked with GLW. It was found that The growth was nill in case of GLW treated sample.The study is on laboratory scale and to check out the efficacy of GLW as fungal growth inhibitor on wood logs, it can be studied at mill site on wood logs. However it would certainly be effective for wood logs, where growth of fungi is mild.

Treatment of Chips with Fungi

Based on the fungal strains found commonly in stored wood samples collected from mills under study were used for laboratory experiments. Phanaerochaete and Penicillium which were commonly found in most of the stored wood samples were selected for inoculation of Eucalyptus .Raw material stored in moist climatic condition had shown growth of fungus on its surface.

Dose of green liquor washings applied

Weak Green Liquor washings with a strength of 16.12 g/l as Na_2S was collected from a nearby pulp & paper mill. 1% of GLW (w/w)was applied on eucalyptus chips.

Three set of chips were stored in batches of four to draw the sample after each 15 days. Following are the details of the sampling carried out

- Control sample
- Chips treated with only fungi
- Chips treated with fungi and Weak Green Liquor washing (GLW)

Each Sample was subjected to the Following Analysis

1. Proximate chemical analysis
2. Pulping experiments
3. Physical strength Properties evaluation
4. Bleaching studies

Results of experiments revealed that Weak Green Liquor washings can effectively be used as fungicide, which aids in preserving the fiber during storage of raw material.

1. Proximate chemical analysis

The results of proximate chemical analysis are given in Table -4

Table 4 -Results of Proximate chemical analysis of green liquor treated eucalyptus sample

Parameter	After 15 days			After 30 days		
	Control	Nutrient+Fungi	Nutrient +FungiGLW	Control	Nutrient + Fungi	Nutrient +Fungi+GLW
Alkali solubility (N/10), %	13.00	15.70	13.61	13.90	15.00	13.60
Total lignin content [1], %	30.64	29.78	29.94	30.66	29.71	31.75
Holocellulose content [2], %	71.50	73.33	71.21	75.00	70.01	70.80
	After 45 days			After 60days		
Alkali solubility (N/10), %	14.60	16.60	14.0	14.60	16.70	14.5
Total lignin content [1], %	30.92	31.62	30.80	31.48	32.67	32.24
Holocellulose content [2], %	73.86	72.42	72.73	75.62	73.00	70.00

Table 5 : Result of pulping experiment after 15 & 30 days

S.No	Parameter	After 15 days			After 30 days		
		1	2	3	1	2	3
1.	Weight of sample, g	350	350	350	350	350	350
2.	Sample wt after treatment, g	336.3	288.5	331.5	349.2	315.0	336.0
3.	Loss of weight%	3.91	17.71	5.28	nil	10	4.0
4.	Unbleached pulp yield,%	45.1	42.8	44.0	44.60	37.81	44.25
5.	Unbleached Pulp kappa number	17.5	15.0	17.0	20.0	18.0	19.0
6.	Unbleached pulp brightness, %ISO	26.92	27.94	26.87	29.17	28.28	34.26
7.	Unbleached Pulp viscosity, cc/g	610.45	578.70	627.13	840.6	668.6	809

Table 6 : Result of pulping experiment after 45 & 60 days

S.No	Parameter	After 45 days			After 60 days		
		1	2	3	1	2	3
1.	Weight of sample, g	350	350	350	350	350	350
2.	Sample wt after treatment g	349.7	330.42	345.18	338.2	324.9	333.9
3.	loss of weight%	nil	5.6	1.37	2.0	7.17	4.6
4.	Sample taken for pulping, g	200	200	200	200	200	200
5.	Unbleached pulp yield,%	43.4	41.90	43.0	42.95	40.6	43.60
6.	Unbleached pulp kappa number	16.63	13.6	16.17	12.5	14.2	13.6
7.	Unbleached pulp brightness, %ISO	28.94	28.64	32.08	28.9	29.10	30.5
8.	Unbleached pulp viscosity, cc/g	555.85	532.71	540.0	437.0	422	418.0

Table 7 : Physical strength properties of unbleached pulp of eucalyptus ~300 ml freeness

	Control				Fungi treated				Fungi+GLW treated			
Days	15	30	45	60	15	30	45	60	15	30	45	60
Burst index KPam^2/g	5.80	5.35	4.6	4.9	4.60	4.45	3.90	4.45	5.40	5.40	4.70	4.90
Tear Index mNm^2/g	7.40	7.45	7.00	6.40	6.80	6.50	6.80	6.30	7.15	7.90	7.50	6.40
Tensile index Nm/g	77.0	73.0	73.0	72.5	73.5	61.0	62.0	61.0	78.0	73.0	66.0	71.5

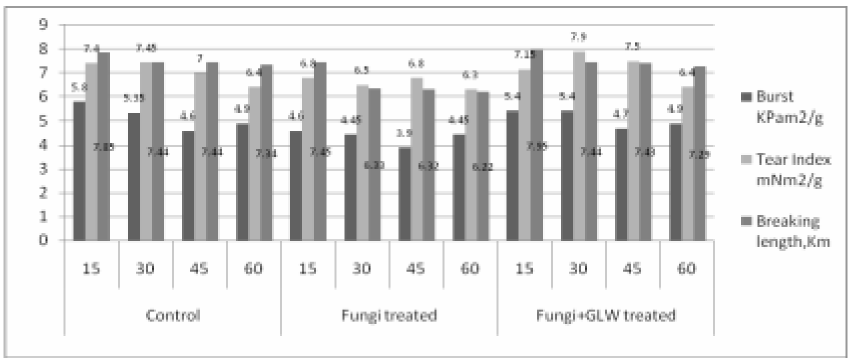

Fig 6 The physical strength properties of eucalyptus pulp

Parameter	1	2	3
Unbleached pulp kappa number	16.6	13.6	16.2
Intrinsic viscosity (cm^3/g)	555.85	532.71	520.0
Unbleached pulp brightness, %ISO	28.94	28.64	32.08
Bleaching sequence applied	DEpD	DEpD	DEpD
Chlorination /Dioxide Stage			
Dioxide added, as avl. chlorine, %	4.0	3.4	4.0
pH	2.5	2.5	2.5
Extraction stage (Ep)			
NaOH added, %	2.0	2.0	2.0
Peroxide added, %	1.0	1.0	1.0
pH	11.0	11.0	11.0
DEp kappa number	3.2	3.0	3.3
Dioxide Stage			
Dioxide added, %	1.0	1.0	1.0
Dioxide consumed, %	0.89	0.85	0.90
Brightness, %ISO	81.5	82.0	81.5
Viscosity, cm^3/g	502	394	500

Table 8: Bleaching of eucalyptus pulp

Pulping Experiments

The results of pulping experiment are depicted in **Table 5 and 6.**

1. Sample control
2. Sample + fungi
3. Sample + fungi + Green Liquor Washings

Physical Strength Properties of Unbleached Pulp

The results of physical strength properties of are depicted in Table 7 and fig 6.

1. Sample control
2. Sample + fungi
3. Sample + fungi + Weak Green Liquor

Bleaching Study of Eucalyptus Pulp Samples

Studies on bleaching of eucalyptus pulp samples were carried out to check the impact of GLW treatment on pulp bleachability. The DEpD bleaching of pulp was carried out and results are depicted in **Table 8**

1. Sample control
2. Sample + fungi
3. Sample + fungi + Weak Green Liquor

Observations

- The Weak Green Liquor washings (GLW) treated chips showed substantial preservation of fibrous raw material. In the present study the fungal treated chips without GLW treatment showed weight loss of around 6.0-8.0% when compared chips treated with Weak Green Liquor and fungus. (table 5)
- The ash content has been observed higher in case of Eucalyptus chips of fungi & green liquor treated in comparison to control and fungi treated chips. Weak Green Liquor washings contain sodium sulphide, salt which contributes in the analysis of ash and results in higher ash content in case of fungi & green liquor treated chips.
- The yield loss after pulping also indicated the degradation of fiber from 1.0-3.0%, in case of fungal treated raw material.
- Intrinsic strength of fiber after pulping dropped in case of fungal treated chips. A comparison of viscosity of pulps of controlled sample, G.L.W treated chips and chips treated with fungi (without GLW) after 15 days storage cooked under identical conditions of pulping revealed drop in viscosity from 610.45 cc/g (control), 627.13 cc/g (GLW treated)) to 578.70 cc/gm (fungal treated). The similar trend followed in case of samples of higher storage period. (table 6)
- No negative impact of GLW treatment on pulp brightness after DEpD bleaching has been observed.
- Results of physical strength properties of pulps in above three sets were evaluated (control, only

fungal treated and GLW and fungal treated

- The strength properties of controlled and GLW treated samples were identical. The Tear index of only fungi treated pulp dropped (after 15 days) from 7.40 $m.Nm^2/g$ to 6.80 mNm^2/g, . tensile index is also reflect the same trend while burst index affected marginally. (fig 6)

Conclusions:

1. Storage of raw materials either wood or agro based results in deterioration with time.
2. The ideal storage period which most of the mills follow is 2-3 months.
3. The climatic conditions were found to be the most influential factor for the preservation of raw material on storage. The extent of degradation was higher in humid climate.
4. In wet or high humid climate (mills in eastern and north eastern part) the degradation of raw material was higher due to the fungal attack.
5. Fugal attack on raw material results in degradation of raw material, due to this the alkali solubility increases significantly.
6. Studies on the effect of storage of pulp wood revealed that untreated material invariably attacked by borer and fungi while treated material degraded less.
7. Borer and fungus attack influence pulp yield and causes appreciable decrease in strength properties of paper
8. The physical strength property that affected most in all raw materials is the tensile strength.
9. Drop in tensile strength is sometime to the extent of ~ 30% after storage of raw material for 6 months in comparison to fresh sample.
10. Even a saving of 2% in pulp yield would result into saving of pulp wood of 4%. For a 100 TPD mill a saving of 4% in wood could lead to a saving of approx Rs. 50,000/- per day or 1.65 crore per annum.
11. The loss of storage can be prevented by use of preservatives. Mills are applying phosphorus and chlorine based pesticides for this purpose.
12. Weak washings of Green Liquor which has no further use may be applied as wood preservative. The study was carried out on Eucalyptus chips.
13. It has been concluded with the study that GLW treated wood shows preservation of yield and strength substantially. However the upper surface of raw material get darkened due to alkaline nature of GLW, but further studies of pulping and bleaching has no impact of darkness on pulp brightness. Even unbleached pulp brightness of GLW treated chips pulp found higher than untreated one.
14. The study needs to be validated at mill scale, on wood logs stored at mill yard. The dosing of GLW applied on wood stacks will need to be optimized for various raw materials.

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