2.5 Wood Products

2.5.1 Overview

Wood and wood products are selected mainly on the basis of physical and mechanical properties for various end uses besides other properties. Non-destructive testing like ultrasonic and FTNIR spectroscopy techniques that are undertaken may be a potential tool for estimating quality of timber in short duration in comparison to the traditional test procedures and ultrasonic technique may also be useful for the detection of defects in log/ trees. Current research is focused towards using plantation timber; use of FT-NIR and ultrasonics for wood quality assessment; modification of wood surfaces for enhancing its stability, durability and surface qualities; development of new methods of timber drying; testing of exotics and imported species for their durability and treatability; developing surface coating systems, use of plant extract as preservative and lignin in various by products.

Finger jointing as a tool for utilizing economically mill waste has caught the imagination of solid wood industries worldwide. However, this technique is yet to pierce the Indian market. The present utilization is mainly on non-load bearing members like table tops, frames of flush doors etc. FRI has initiated research into utilizing finger joints for structural and semi-structural uses. In this direction a project on laminated short beams of different species was concluded. Results are indicative of finger jointing being effective in *Ailanthus excelsa, Populus deltoides* and *Mangifera indica* wherein more or equal bending strength and elasticities were observed as compared to those in laminated beams of solid sections without finger joints.

Drying behaviour of timber of Chir pine and Shisham wood was studied in a self designed convection-heating type vacuum kiln. Treatment methodology for Douglas fir with ZiBOC developed. Complete protection of Meranti (Red, Yellow and White) and Douglas fir is yard test could be achieved after treatment with ZiBOC, CCA and CCB after 20 months of installation. Two species of timber (*Acacia auriculiformis* and *Hevea brasiliensis*) were thermally treated at different temperatures under different environments (vacuum and nitrogen atmosphere). Certain physical and mechanical properties were determined and compared with untreated samples. Dimensional stability and colour of the wood samples were improved due to thermal modification which makes the material more suitable for flooring applications. Thermal treatments are found to be effective against termites in soft wood but not in hard wood. Twenty two imported species of different country of origin were evaluated for natural durability in Dehradun test yard. After 36 months, samples of all species were badly decayed except teak of Myanmar, Ghana and Tanzania. Performance of *Pinus roxb.*, *Pinus radiata, Pseudotsuga menziesii* in prototype cooling tower with CCA, CCB and ZiBOC preservative revealed that *Pinus radiata* performed badly as compared to other species.

Physical and mechanical properties of *Bambusa bambos* (L.) and *Dendrocalamus strictus* (Roxb.) have been carried out to find their suitability as an alternative of wooden dunnage pallets. Wood quality of clones of *Eucalyptus tereticornis*, *Eucalyptus eurograndis* and Acacia hybrid have been carried out for finding the suitability of clonal material for handicraft sector.

A solvent free process has been developed concerning the chemical modification of wood by acetic anhydride and butyric anhydride with iodine as catalyst. The presence of small amount of iodine elevated the conversion rate of modification significantly. This finding has commercial implications

as reduction in treatment time will bring down the cost of modified wood.

Properties of thermally modified rubberwood and silver oak were evaluated. Heat treatment resulted in colour darkening and improved dimensional stability although a significant loss in static mechanical properties was observed.

Project under the Theme			
Projects	**Completed Projects**	**Ongoing Projects**	**New Projects Initiated During the Year**
Plan	04	12	06
Externally Aided	02	01	00
Total	**06**	**13**	**06**

2.5.2 Wood and other Lignocellulosic Composites

Plantation grown wood like poplar and eucalyptus are mostly being used extensively in plywood industries. Therefore, plywood industries in the country have been looking for alternative species. As it is difficult to get single species for making plywood, and non-availability of data, the combination plywood may be the solution for this problem. In this direction paper mulberry and in combination with poplar is being tried for plywood. Plywood and other composite wood items are susceptible to fire and degradation. However, on treatment with fire retardant chemicals, glue shear strength of plywood decreases. Therefore, to overcome this weakness, different fire retardant and preservative compositions were being tested on plywood to evaluate their effect on glue shear strength.

Jute and wheat husk were explored as a reinforcing materials for bio-fiber filled polypropylene composites. Composites with varying proportion of jute and wheat husk (10% to 50%) were prepared with and without compatibilizer. Jute filled composites exhibited superior mechanical properties than wheat husk filled composites. At 50% jute content, tensile strength, flexural strength and tensile modulus exhibited 87%, 95% and 300% increase, respectively over virgin polypropylene. Whereas, for wheat husk, these properties exhibited a marginal improvement. M-TMI-g-PP was proved to be a better coupling agent than MAPP.

Cellulose HDPE and HDPE co PP composites were prepared using Cellulose supported catalyst system. For one step synthesis of cellulose filled composites a high pressure gas-liquid slurry reactor system with metered feeding of gaseous monomer and a catalyst feeding system was used. Experiments were conducted to study the effect of monomer to comonomer concentration and catalyst to cocatalyst ratios on polymerization yield. Molecular weight was determined by gel permeation chromatography. A kinetic model for ethylene homopolymerization was developed to predict instantaneous reaction rates. The kinetic rate constants for initiation, propagation, chain transfer and deactivation were estimated using a systematic optimization strategy. It was found that the reaction rates increases with temperature and monomer and catalyst concentration (pressure). Temperature exhibited strong negative influence on molecular weight. Pressure has little effect on Mn but high pressure produce polymer with higher polydespersity (PDI). Higher catalyst content will produce low molecular weight polymer.

All the experiments planned to study the effect of concentration of nanoclay, use of additives, method of incertation of nanoclay, and wood content on properties of composites are completed. All the formulations were moulded into test specimens and evaluated for mechanical performance as per ASTM standards (Impact strength both notched and un-notched, Flexural strength, Tensile strength and MoE). Microstructure-based FEA models in 2D were developed to study the mechanical behavior of montmorillonite-filled polypropylene

nanocomposites. Monte Carlo simulation gave the range of modulus values. Mean values of the modulus obtained by Monte Carlo simulation is in agreement with the experimental results.

Experiments on Extraction of cellulose nowhiskers by acid hydrolysis, tempo oxidation method and enzyme hydrolysis method completed. Effect of temperature and sonication time on yield studied. Nanocellulose was prepared using a combination of mechanical (ultrasonication and high pressure homogenization), Chemical (acid hydrolysis and enzyme hydrolysis, and tempo oxidation) and using a combination of mechanical and chemical methods. Achieving nano cellulose with pure mechanical methods was very difficult. High shear forces were thermally degrading the cellulose extensively and high pressure homogenization was getting clogged very frequently. Only chemical methods were able to reduce the size upto 200-300nm. For further reduction mechanical treatment was necessary. Acid hydrolysis and tempo assisted oxidation produced best results with fiber diameter in the range of 40 to 130 nm and lengths of several hundred nano meters. Enzyme hydrolysis did reduce the size but it was too large for processing in homogenizer. The homogenizer was getting clogged very frequently and due to large size shear induced thermal degradation was also taking place. Grafting of MMA for preparation of nanocomposites completed. Cellulose nanowhiskers were grafted with polylactic acid and compounded with neat polylactic acid. Specimens preparation as per ASTM standards evaluation of mechanical properties is under progress.

For development of Natural Fiber-PVC composites for light structural applications, a high speed mixture and specific screw elements were procured. A new screw has been designed and fabricated for blending of PVC with lignocellulosic fibers. Rehological behaviour of PVC blended with different fibers (Wheat husk and coir) having different levels of loading ranging from 10% to 50% and with two coupling agents (in house developed m-TMI-g-PP and commercial grade MAPP) were carried out to study shear effect and torque with time. PVC-coir composites were characterized by FTIR.

2.5.3 Wood Processing

An indigenously designed convection heating type vacuum kiln has been installed in 2010-11 in the Wood Seasoning Discipline, FRI Dehradun. Drying behaviour of timber of Deodar, Toon, Chir pine and Shisham wood was studied in this kiln. The drying time of these timbers reduced remarkably in the vacuum kiln as compared to the conventional steam-heated kiln. The vacuum kiln is clean energy based emission free timber drying technology.

Vacuum Kiln for Timber Drying Developed by FRI, Dehradun

2.5.4 Value Addition and Utilization

Due to environmental concerns regarding the use of certain classes of preservatives, there has recently been a renewed interest in alternative methods for wood preservation. Different heat treatment techniques are tried to improve durability of wood. Modification of wood is also tried to improve durability. There is scarcity of suitable wood for cooling tower industry; therefore the study to find out alternate species and preservatives which can give substantial life to cooling tower is being tried. Imported species are also being studied for their performance in three agro climatic

condition for their natural durability and durability after treatment.

Under the study on constraints in the export of carved out wood products and its economical and social impact on the livelihood of dependent people in-north India, literature regarding distribution of Wood Carving Industry, its economic contribution and identification of problems with focus on raw material procurement, manufacture of carved out wood products and their marketing has been studied. Ten wood carving centres have been selected throughout North India viz. Srinagar, Rajouri, Chamba, Kullu, Hoshiarpur, Amritsar, Saharanpur, Nagina, Udaipur and Jodhpur. Reconnaissance survey has been undertaken. Questionnaires have been developed in such a way so as to assess the economic condition, literacy level, specialization, working tools or machines (technology) used, number of working months, alternate source of income, type of working, constraints in the development of skill and economic upliftment.

Chemically modified (benzoylated and acetylated) wood specimens of Rubber wood (*Hevea brasiliensis*) and Radiata pine were coated with a transparent and opaque polyurethane exterior paint. The coated panels were exposed to outdoor weathering and samples were periodically examined for weathering deteriorations. Results indicate that performance of coating on modified wood was remarkably improved as compared to unmodified specimens. Chemically modified wood, improved coatings adhesion and enhanced performance of paints significantly.

Analysis on the quantum and types of woods imported in India revealed, teak as the most preferred species of import. Based on the cumulative natural resistance in the graveyard conditions, major imported timbers were classified. Accordingly the highly resistant woods were *Dryobalanops aromatica, Tectona grandis* (from five countries), *Shorea laevis, S. marcoptera, S. robusta, Pterocarpus soyauxii* (from two countries) and *Xylia dolabriformis*. *Quercus robur* was moderately resistant to termite attack. *Fagus sylvatica* (from two countries), *Fagus grandifolia, Fraxinus angustifolia, F. excelsior*, *Acer pseudoplatanus* were susceptible to termite attack. All the tested imported species performed more or less in the same way as in marine condition. In general, woods from temperate regions were found more susceptible to termites than that of tropical regions. The study on the seasonal wood degradation activity of four species of *Odontotermes* viz., *O. horni*, *O. feae*, *O. obesus* and *O. wallonensis* revealed that all the four species were active throughout the year. Peak abundance of *O. obesus* was in the month of May, whereas for *O. wallonensis* it was from April to May. *O. feae* was active throughout the year and *O. horni* was highly active during June and August. The strength properties of resistant woods remain more or less the same and comparable before and after exposure for a period of one and three years.

Ten, 15 & 20 yrs old timber of *Acacia auriculiformis* and *A. mangium* showed good resistance against both decay fungi and termites and they may be classified under Class I; whereas, 5 yr timber comes under Class II. *E. tereticornis* are highly resistant (Class I), *G. robusta* belongs to class III and *M. dubia* falls under non-resistance class (IV). *Ailanthus* species exposed to termites and fungus showed that they belong to the durability class III with service life less than 60 months but resistance of *A. malabarica* is more than *A. excelsa*. All the age group timbers of *Grevillea robusta*, from both the wet and dry regions fell within the resistant to moderately resistant class when tested against decay fungi under laboratory conditions. Timber from 5 year old trees was destroyed completely by termites within 4 years of exposure in test yard. While 10 year samples showed retention between 35 and 50 %, 15 and 20 year timber samples showed good resistance (80–100 %) up to 3 years of exposure. The susceptibility to termite attack reduced as the age of the tree increased. Any age group of *Maesopsis eminii* is not naturally resistant. Studies revealed that durability is affected by the tree age and the source of the timber.

Chemical modification of wood (Rubberwood and Silver oak) has been carried out using octanoyl and lauoryl chloride. Reaction parameters were optimized. Chemical modification of wood using alkylene epoxides viz., propylene oxode and butylene oxide carried out. Esterified / etherified wood was characterized using FTIR and NMR spectroscopy. TGA analysis of Esterified wood was carried out. Properties of wood modified with acid chloride (dimensional stability, UV resistance and fungal resistance) completed. Modified wood flour was pressed in a hot press at 150 ^{0}C. Modified wood particles became softer and show thermoplasticity and self bonding effect.

The work carried out for developing technologies for protection of wood for exterior applications, particularly through chemical modification and thermal treatments. A solvent free process has been developed concerning the chemical modification of wood by acetic anhydride and butyric anhydride with iodine as catalyst. The presence of small amounts of iodine elevated the conversion rate of modification significantly. Rubber wood was esterified with phenylisothiocyanate, and dimensional stability, decay resistance, and photo stability of the modified wood assessed. Unmodified and modified samples were exposed to a brown rot (*Polyporus meliae*) and a white rot *(Coriolus versicolor)* fungus for 12 weeks. Modified wood samples exhibited good dimensional stability and were very resistant to decay. However, phenylisothiocyanate modification of wood was not effective in decreasing photo-yellowing. Rubber wood esterified with fatty acid chlorides exhibited good dimensional stability, degree of dimensional stability increased with increasing carbon chain length. Treated wood was partially effective in inducing stability against UV light irradiation. Modified wood samples exhibited very good resistance to brown rot and white rot fungi. Dispersion of ZnO nanoparticles in maleic anhydride modified polypropylene (MAPP) enhanced UV resistance of wood polymers, indicating potential of nano-particle based wood coatings in future for providing protection from harmful UV radiation in outdoor environment. Properties of thermally modified rubberwood and silver oak were evaluated. Heat treatment resulted in colour darkening and improved dimensional stability although a significant loss in static mechanical properties was observed.

Under the study to find the suitability of bamboo for dunnage pallets, Determination of physical properties has been completed. Studies on mechanical properties under green condition are in progress. Consulted the officials of Central Warehousing Corporation for designing of pallets.

Under the comparative study of clones of Eucaly and *Acacia* hybrid for handicraft sector physical properties (specific gravity, moisture content and shrinkage) were studied. Studies on mechanical properties under green conditions completed and that for air-dry samples is under progress. Observed air seasoning behaviour on small planks for all the clones. Gross anatomy of *Eucalyptus* clones completed and that for *Acacia* hybrid is under progress. Studies on wood working qualities are under progress. The properties are being evaluated to assess the wood quality of clonal material for handicraft sector.

Thermal processing of different wood species namely *Acacia auriculiformis* and Rubber wood were carried out at different temperatures in the range of 150 to 240 $^{\circ}$C under different environment such as vacuum, air and nitrogen. Physical and mechanical properties of small clear specimens are being carried out as per BIS standard. Colour and surface roughness test were also carried out on heat treated and control specimen. Samples of treated and un-treated wood were installed in grave-yard and observations are being made to access the extent of decay.

Preservative treatment of rubber wood and *Melia dubia* wood were carried out using micronised copper under vacuum and pressure cycle for two pressure duration of 1 and 2 hours. Specific gravity and shrinkage studies were completed. Mechanical properties are being evaluated. Data on leaching are being collected.

Specimens for durability tests were prepared and observations are being made against wood decay and durability in the grave-yard test.

Under the study on screening of oil of *Pongamia pinnata* Linn., *Jatropha curcus* Linn. and *Simarouba glauca* D.C. for developing eco-friendly wood preservatives oils of *Pongamia pinnata*, *Jatropha curcus* and *Simarouba glauca* were incorporated with copper metal by refluxing with Cupric oxide. Treated rubber wood specimens with metal ions incorporated oils of *Pongamia pinnata*, *Jatropha curcus* and pure oil of *Simarouba glauca* by different methods. Laboratory tests of treated and control specimens against wood decay fungi is in progress. Borer test in the laboratory with powder post beetle larvae is in progress. Installed 135 specimens of treated and control samples in the test yard for field exposure, following randomized block design.

Preservative based on extractives of *Acacia auriculiformis*, *Acacia nilotica*, and *Gliricidia sepium* were prepared. Specimens were treated by pressure method by "Full cell" process following 15'/50/60'/5', initial vacuum for 15minutes, pressure of 50 psi for 60 minutes followed by a final vacuum for 5 minutes. Absorption of each of the specimen was calculated by weight gain method before and treatment. Treated specimens were installed in the Test-yard at Nallal along with untreated controls for field exposure, by half buried in the ground, Grave-yard test, 145 Nos were installed A field chart about the position of each specimen was prepared. Laboratory tests of treated and control specimens against wood decay fungi is in progress. Borer test, exposing the specimens to borer is in progress.

Under the study on Nanoparticles based wood coatings for outdoor applications, the equipments (Reflectance Accessory for UV spectrometer and Homogenizor) were procured. The experiments on dispersion of nanoparticles in polyurathane coating carried out. UV resistance of rubberwood coated with zinc oxide (ZnO) nanoparticles dispersed polyurethane exterior clear coating was evaluated.

Under the study on wood quality, variability in sawn timber from three plantation grown species, a warp measuring table has been commissioned. The table can measure extent of bowing, cupping and twisting in boards. The measuring procedure has been standardized with the six feet long boards. Methods for measuring resonance frequency and acoustic velocity in boards have been established. Silver oak planks (50 cft) have been procured and acoustic velocity in these boards in initial condition has been measured. An initial investigation on the effect of moisture content variation with acoustic velocity in silver oak wood samples has been carried out with small samples. Measurement of other wood quality traits is under progress. Samples for density measurement, shrinkage measurement and quality gradient are prepared and initial measurements are completed. Acoustic velocity in green board varied from 2.20 km/s to 3.89 km/s suggesting stiffness variation from 5.0 GPA to 15 GP-a. Similarly pilodyn penetration also varied from 28 mm to 37 mm in the boards.

Study was done to develop Near infrared spectroscopy (NIR) based high throughout application methods for evaluating physical, chemical and mechanical properties. NIR methods have been developed for specific gravity, bending properties (MOE- modulus of elasticity, MOR- modulus of rupture and FS at LP – Fiber stress at limit of proportionality), lignin and holo-cellulose estimation. The methods are now ready for use in place of conventional one. Upgradation of NIR methods is a continuous process and will be done on regular basis by enlarging NIR library.

Wide variations in properties of 47 phenotypes of *E. tereticornis* have been observed. Specific gravity has varied from 0.494 to 0.767 and similarly other strength properties, making a good case for further selection of material with desired traits. Lignin content varied from 26 to 32% and holocellulose content from 65-72%. Combination of different triats can be used for developing the material for further propagation.

Development of NIR methods will help in reducing cost, time and efforts in assessing wood quality of eucalyptus in future programmes. NIR is of great relevance for quick assessment of the properties. The advantage is that all the properties can be evaluated simultaneously on the same samples with no extra time and cost. This was not possible till now with conventional methods.

Two wood species viz. *Eucalyptus* sp. and *Pinus roxburghii* were studied for quality assessment through ultrasonic technique and conventional test procedures. The relationship of ultrasonic velocity measured by direct pulse transmission method has been established with strength properties determined under static bending and compression tests. On the basis of developed regression models of ultrasonic velocity with strength properties, timber material can be sorted out/graded in to the different grades (strength-wise). Ultrasonic velocity decreases with increasing moisture content in timber up to the fibre saturation point (F.S.P.) and also above the F.S.P. Ultrasonic velocity was found to be higher along the longitudinal direction than transverse ones (radial/tangential) of timber. Generated data on defect indicate that speed of ultrasound decrease significantly in the presence of structural irregularities (centre hollowness, cracks etc.) in timber. Centre hollowness/ cracks and its size detected successfully by ultrasonic technique. But hollowness and multiple cracks in timber disc may not be distinguished by ultrasonic defect detection technique. Testing of log can be performed for defect detection (hollowness/multiple cracks) in the field. Ultrasonic testing technique developed for defect detection in log was also applied in the tree trunk of different tree species viz. *Mangifera indica*, *Dalbergia sissoo*, *Delonix regia* and *Eucalyptus* spp. Current status of these trees was identified. The new study to enhance the strength of finger joints through manipulating the L/P ratio of the profiled fingers initiated in the last year was continued. Preliminary results are expected in the coming year.

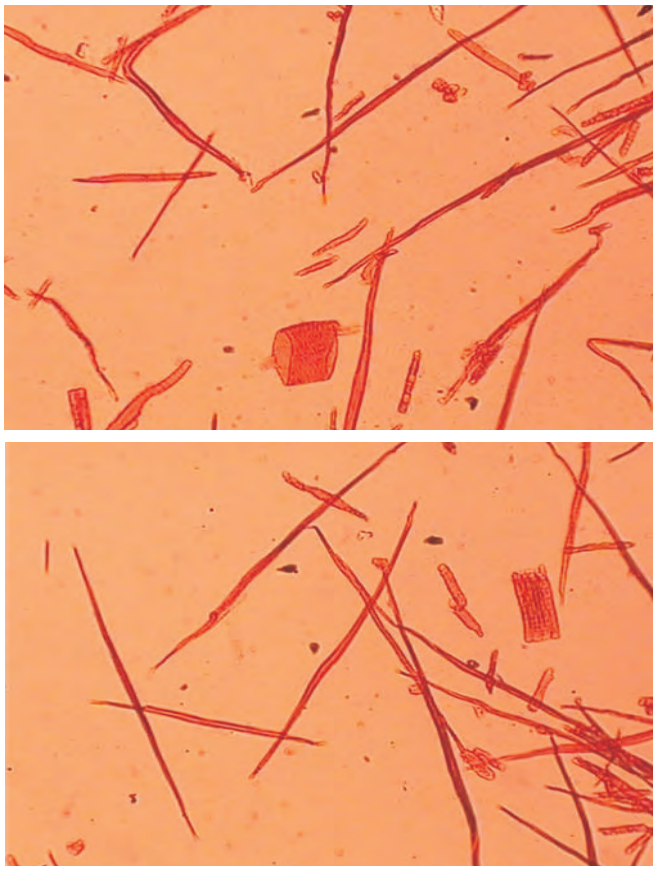
2.5.5 Pulp and paper

In the study on Evaluation of Alternative Raw Materials for Pulp and Paper making, anatomical analysis in terms of fiber length, outer diameter, lumen diameter, wall thickness, vessel length, vessel diameter, runkel ratio and fiber shape factor was carried out for *Melia composita*, *Prosopis juliflora* and *Gmelina arborea* by Schultz method. In case of *Melia composita* the average fiber length was 870.3 μm, outer diameter 15.67 μm, lumen diameter 7.0 μm, wall thickness 4.33 μm, vessel length 217.13 μm, vessel diameter 140.63 μm, runkel ratio 1.23 and fiber shape factor was 0.66. In *Prosopis juliflora* the average fiber length was 1215.6 μm, outer diameter 33.5 μm, lumen diameter 23.0 μm, wall thickness 5.25 μm, vessel length 387.60 μm, vessel diameter 246.8 μm, runkel ratio 0.45 and fiber shape factor was 0.35, however, in case of *Gmelina arborea* the average fiber length was 899.6 μm, outer diameter 24.9 μm, lumen diameter 15.1 μm, wall thickness 4.9 μm, vessel length 316.0 μm, vessel diameter 156.4 μm, runkel ratio 0.64 and fiber shape factor was 0.46. Pulping of the proposed raw materials i.e. *Melia composita, Prosopis juliflora* and *Gmelina arborea* was done by Mechanical and Chemical methods.

Mechanical pulping of *Melia composita, Prosopis juliflora* and *Gmelina arborea* was carried out with 8%, 10%, 12%, 14% and 16% NaOH (cold soda process), however, chemical kraft pulping was carried out at different cooking time periods i.e. 30, 60, 90 minutes at 170°C, with sulfidity 15, 20, 25% having chemical charge 14, 16, 18%. Analysis of unbleached pulps was done for yield, Kappa number and CSF. The lowest Kappa number was 31.49 with the yield of 45.75% in case of *Melia composita* during kraft pulping while it was 16.61 with yield of 49.12% in case of *Prosopis juliflora*. In *Gmelina arborea* the yield and lowest Kappa no. of unbleached pulp was 51.44% and 16.32 respectively. For evaluation of unbleached pulp, the pulp was subjected to beating and the beaten pulp was evaluated for strength properties (Tear Index, Tensile

Index and Burst Index). For evaluation of strength properties, hand sheets of 60 gsm were prepared by laboratory sheet making machine.

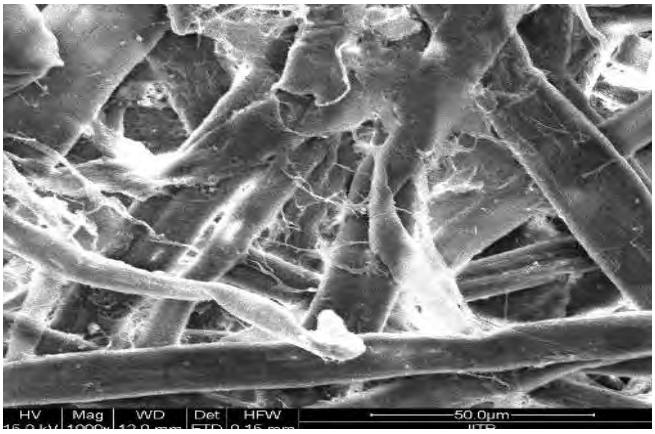
In another study on Evaluation of *Sesbania grandiflora* and *Lannea coromandelica* for papermaking, proximate chemical analysis of *Sesbania grandiflora* received from ITC, Bhadrachalam was carried out for ash content, solubilities (cold, hot water, alcohol-benzene, 1% NaOH), holocellulose, Alpha (α)–Cellulose and klason lignin. The ash content was 2.5%, solubilities ranges from 2.5 to 13.25%, holocellulose content was 68% with 41.65% Alpha (α)–Cellulose and klason lignin was 26.0%. Fibre length, lumen diameter, wall thickness, vessel length, vessel diameter Runkel ratio & fibre-shape factor were 1135, 19.9, 5.26, 358.08 and 161.42μm, 0.51and 0.38 respectively for *Sesbania grandiflora*. The values of fibre length, lumen diameter, wall thickness, vessel length, vessel diameter, runkel ratio and fibre- shape factor for *Lannea coromandelica* were 1025.86, 29.47,19.61,4.92,178.08μm 0.59 and 0.38 respectively. Pulping of *Sesbania grandiflora* under varying kraft cooking conditions (14-18% as Active alkali, 740-1200 H factor) was completed. The total yield varies from 40-44% with kappa numbers 31-40. The physical strength properties with respect to tensile burst and tear indices were 90, 7.9 and 6.63 respectively which indicate that good quality of strong kraft paper can be prepared from *Sesbania grandiflora*. Black liquor collected under varying kraft cooks were analyzed for pH, total solids and Residual active alkali. The results obtained so far indicate the pH (9.2-11.1), total solids (12.2-20.5) and RAA (1.86-8.68).



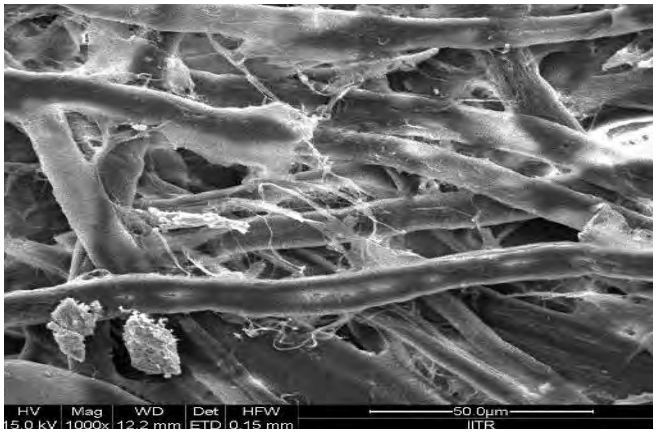
Microscopic Features of Fibers

For the Biodeinking of waste paper, the cultivation conditions (incubation period, pH and temperature) were optimized for *Trichoderma viridi* and *Coprinus disseminatus* for enzyme production. Best incubation period of eight days was observed for *Trichoderma viridi* and fourteen days for *Coprinus disseminatus*. Moisture level was optimized at various ratios of 1:1, 1:2, 1:3, 1:4 and 1:5 and the maximum cellulase activity at 1:3 carbon source was observed for *Trichoderma viridi,* however, it was 1:2 in case of *Coprinus disseminatus*. To obtain optimal pH, *Trichoderma viridi* and *Coprinus disseminatus* were cultivated with different pH ranges from 3.0, 4.0, 5.0, 6.0, 7.0, 8.0 and 9.0 pH with Substrate: Wheat Bran at optimum condition and the maximum enzyme activity at pH 4.0 was observed for *Trichoderma viridi,* however, it was pH 5.0 in case of *Coprinus disseminatus*. Temperature was optimized by incubating the flasks at a range of 20^{0}C to 40^{0}C. The results showed that the maximum cellulase activity was at 30^{0}C for *Trichoderma viridi,* however, it was 35^{0}C for *Coprinus disseminatus*. The optimal activity of produced enzyme by *Trichoderma viridi* and *Coprinus disseminatus* was tested in the range of 3 – 9 pH, and pH 5 was found optimal for *Trichoderma viridi* and pH

Untreated Deinked Pulp



Chemically Deinked Pulp



Enzymatic Deinked Pulp

6.5 for *Coprinus disseminatus* for maximum enzyme activity. To obtain optimum temperature, the optimal activity of produced enzyme by *Trichoderma viridi* and *Coprinus disseminatus* was checked in the range of 30^{0}C – 80^{0}C, and the optimum maximal enzyme activity was found 45^{0}C and 50^{0}C for *Trichoderma viridi* and *Coprinus disseminatus* respectively. Chemically and enzymatic deinked pulp was analyzed under Scanning Electron Microscopy (SEM).

Enzymatic deinking parameters i.e. enzyme dose, pulping time and consistency, optical properties (ERIC value, Brightness, Opacity) and other physical properties of paper sheet (tear index, tensile, burst and double fold) were evaluated.