CHAPTER I

INTRODUCTION
Paper is one of the most indispensable commodities in the modern world. From the traditional use for writing and printing to the more esoteric applications in fashion and housing, paper has pervaded every aspect of human life. It is an important means of transmission of thoughts through newspapers, books and journals.

Chemically paper comprises of mainly cellulose alongwith hemicellulose and lignin with minor extractives. Its manufacture requires a specialised knowledge of technology. It is made from fibrous raw material and the most important sources of which are the forests of the world. Fibres are cells of a tubular structure whose walls are made up of more or less pure cellulose. Woods which gives good quality pulp is most suitable for paper making. Fibres from different sources have different physical properties like length, width, wall thickness, cavity diameter, in addition to their varying chemical composition like varying amounts of main constituents of wood-cellulose, hemicellulose, lignin and extractives\textsuperscript{1}. The fibres most commonly used for paper making are those derived from wood, while smaller amounts of cotton (rag or linters), straw, flax, grasses and other vegetable fibres are also used commercially. At present papers are also made of glass and synthetic fibres which find specialised use for chromatographic or filtration purposes.

The various steps involved in the manufacture of paper are as follows :-
PREPARATION OF RAW MATERIAL:

Prior to pulping operation, wood requires debarking, splitting and cutting into logs and then chipping the logs into suitable chip size. This facilitates penetration of cooking liquor in the chemical process. Grasses and straw do not require any special treatment before pulping. Bagasse needs depithing while materials like jute sticks need chopping due to their bulk. Rags, waste cloth, cotton lint, old ropes, nets and sacks, hemp and jute are sorted, chopped and dusted before pulping.

PULPING:

Pulping processes are of three principal types viz., mechanical, chemical and semi-chemical processes.

Mechanical process: It involves reduction of wood or other raw material to the fibrous state by mechanical means. In this process a block of wood is forced by pressure against a large grinding stone in presence of water. The function of water is to cool the zone of friction, to plastizize the wood substance and to carry away the pulp. The yield of pulp is high in this process (about 90% - 95%), but it is of low purity and involves considerable fibre damage. Only the cheapest papers like newsprint which are likely to be discarded shortly after use are made by mechanical pulp.

Chemical Processes: These involve treating wood chips with chemicals in a digester under controlled conditions of temperature, pressure, time and liquor composition. This removes lignin and other impurities thereby isolating and partially purifying the individual fibres. The pulp yield is low.
(about 43% – 55%) and the pulp purity is higher and there is relatively little fibre damage. There are three major chemical processes of commercial importance, namely the soda, sulphate and the sulphite processes.

In the soda process, a solution of sodium hydroxide in water at around 170°C is utilised for cooking to digest fibrous raw material. In sulphate pulping process, the wood chips are treated with cooking liquor, known as white liquor, under controlled conditions of temperature, pressure and time. The cooking liquor is composed of a mixture of sodium hydroxide and sodium sulphide. The dissolution of lignin in the sulphate process takes place in three stages. The first stage is the adsorption of lignin through the acidic groups of lignin, the second stage is the formation of alkali lignin, which then becomes soluble. The pulp obtained from this process is of dark brown colour.

In sulphite pulping process, the wood chips are cooked with calcium bisulphite (or sodium, magnesium or ammonium bisulphite) solution under controlled conditions of temperature, pressure and time. During sulphite cooking, the sulphonation and delignification of wood takes place through a complex series of chemical reaction/different stages. During the first stage, when the acidity of cooking liquor is rather low, lignin of wood reacts with sulphurous acid to form a solid sulphonic acid. This very strong acid withdraws calcium ions from the cooking liquor and, of course, makes it increasingly acidic. The second stage is essentially a hydrolysis of acetal linkages in the solid
acid followed by further introduction of new sulphonylic groups. The result is formation of soluble lignosulphonylic acid which remains in the waste liquor. The sulphite pulp is much lighter in colour than the sulphate pulp.

Semichemical Pulping: It is a two stage process involving both chemical and mechanical pulping\textsuperscript{10}. It consists of chemical treatment of wood chips for softening and partial removal of lignocellulose bonding material followed by mechanical reduction to fibrous state\textsuperscript{11}. The yield of pulp varies from 55% to 84%.

**TREATMENT OF PULP:**

**Washing:** The cooked pulp obtained from either of the processes is transferred from the digestors as fibre suspension in the residual liquor or black liquor to the washers through blow tank\textsuperscript{12}. The black liquor is separated from pulp and it contains inorganic as well as organic substances. The black liquor is sent to chemical recovery section\textsuperscript{13} and the pulp is finally washed with water.

**Screening and Cleaning:** Screening of pulp is done to remove impurities and uncooked knots\textsuperscript{14}. Screening is first done in screens of different perforation sizes and then in series of centrifugal cyclone cleaners\textsuperscript{15}.

**Bleaching of Pulp:** The purpose of bleaching is to remove lignin present in unbleached pulp to oxidise the colouring matter and to achieve desired brightness of pulp without affecting the strength properties\textsuperscript{16,17}. Pulp is bleached by various
bleaching sequences depending upon the pulping process. Normally bleaching is done by chlorine either in the form of elemental chlorine or by calcium hypochlorite.

Stock Preparation: Fibres are given mechanical and chemical treatment for the development of desired sheet forming and strength characteristics. In the process of beating, fibres are beaten while suspended in water. The effects of beating on the individual fibres are swelling, fibrillation, cutting and removal of primary wall. Swelling takes place in the amorphous, hydrophilic hemicellulosic inter fibriller material. The fibre wall is plasticised by the imbeded water and the fibre becomes more flexible. Because of the fibrillation, a certain physicochemical relationship takes place between the individual fibre and its fibrillae to produce close fibre to fibre bonds in paper during paper formation and drying.

Sizing, Fillers and Loading: Sizing is done to resist spread of or penetration by water or writing ink. A sizing agent is a hydrophilic material eg. rosin, aluminium sulphate etc. Fillers are added to increase the capacity and smoothness of paper. Fillers immediately 'load' or increase the mass of paper.

Paper Making:

The refined blended fibres after stock preparation, centrifugal cleaning and dilution is taken to the machine head box. The stock flow then passes onto a moving Fourdrinier wire. A lot of water is removed by drainage through wire and the paper web is formed. Then the paper is passed to the press section for
further removed of water. The wet paper from the press section containing about 64% moisture is passed to drier section consisting of series of steam heated rolls and dried to about 6% water content. To make the paper smooth, it is passed through calendar rolls. The paper is finally cut into sheets of different sizes according to requirements.

**RECENT DEVELOPMENTS IN PULPING PROCESSES**

To get the good quality pulp at optimum cost various processes of pulping have come into vogue from time to time, depending on situations and needs of the industry. Recent developments in these processes are discussed below:

**Mechanical Process**

The main advantages of the mechanical process are the absence of chemicals costs and the almost quantitative yield from wood, the yield losses being only 2 - 5 percent. The mechanical pulping in grinders has several drawbacks resulting to the pulp of low purity and inferior strength. To achieve acceptable grade of mechanical pulp from lower priced hardwood and softwood saw mill waste, methods have been developed which start from chips and use of disc refiners of various types. Various types of chemical pre-treatments have also been tried from simple addition of sulphite and bisulphite in the refiner to achieve some what brighter as well as stronger pulps. In order to reduce energy consumption with or without chemicals, thermal softening of the inter fibre bonds can be utilised. Hence, during last 10 years, thermomechanical, chemimechanical and chemithermomechanical pulping processes are being developed.
to overcome the drawbacks of mechanical pulp. Ultra high yield pulps are also attracting, increasing commercial interest.

**Semi-Chemical Process**

Semi-chemical process involves chemical treatment followed by the treatment in advanced mechanical fiberising equipment. By addition of chemicals to the grinder showers, it is possible to achieve certain effect. These processes are representing a transitional stage to semi-chemical. As impregnation has been found to be one of the main problems in semi-chemical pulping of bolts, interest soon concentrated on the treatment of chips. Hydrolysis of wood has been studied from different angle and thermal softening has been considered the main purpose of this process. However, the treatment in cold alkali lye at concentrations of 7 - 8 gpl of NaOH followed by mechanical fiberising, gives cold caustic straw pulps in 75 - 85% yield, suitable for corrugating board.

To obtain acid sulfite pulp in high yield, pulping conditions should be chosen to give somewhat slower reactions. Slower reaction is achieved by lower temperature or higher combined SO₂ (lower acidity). The semichemical kraft pulps are obtained in 55 - 70% yield, corresponding to Roe number 17 - 31 for American softwoods. The yield of hardwoods pulps is a little more than 55%.

Pulping in neutral or alkaline sulphite solutions has been repeatedly investigated. A semichemical process using the neutral sulphite process had been worked out by the U.S. Forest Products laboratory. The most common yield range
of 70 - 85% is obtained for well buffered neutral sulfite cooks\textsuperscript{60-63}. Neutral sulfite pulps from Eucalyptus give very interesting paper characteristics\textsuperscript{64}. Hardwood pulps made from this process are frequently stronger than chemical hardwood pulps\textsuperscript{65}. Extremely mild neutral sulfite cooks, giving pulp yield of 95 - 95% from both hardwood and softwood, are also of interest for newsprint\textsuperscript{66}.

**Chemical Process:**

McGovern\textsuperscript{67} has reported that there are three general approaches to high yield chemical pulping process.

1) Improved uniformity of delignification adopting optimisation of pulping conditions.
2) Stabilisation of carbohydrate fraction.
3) Resorption of polymeric carbohydrates in early stages of cooking.

The attack of chemicals on cellulose and hemicellulose depends on the type and concentration of chemicals employed in cooking. The extent of attack on the particular fraction of carbohydrate may be dependent on its degree of polymerisation, manner of combination with other carbohydrates as well as lignin.

**Alkaline Chemical Process:**

High yield kraft pulps in the yield range of 60 - 70% have been obtained by various workers\textsuperscript{68-70} by optimising the pulping conditions. To increase in yields of practical interest, attempts have been made with the use of inorganic chemicals. A systematic search for oxidants have been tested\textsuperscript{71-76}. Sodium dithionite and sodium tetrahydroborate have been investigated\textsuperscript{74-76}.
as oxidant and reductant respectively. The increase in yield was found to originate entirely from an increase in gluco-mannan yield, (6% of wood) and possibly some increase in cellulose yield, (1% of wood).

Polysulfide pulping is one of the recent innovations in the field of high yield pulping. Data of Kleppe\(^7\) based on the experience of mill scale polysulfide pulping indicate that yield could be increased by 15 - 2.0 times the amount of added sulfur. When 20-30 kgs of sulfur per metric ton of pulp dissolved in white liquor charged to a dual vessel Kamyr digester although the sulphidity of cooking liquor was 40-50%. An increase of 6.3% in the pulp yield was observed with addition of 2 - 5% polysulphide sulphur to the cooking liquor.

**Sulphite Process**

The removal of lignin was significantly more by sulphite cooking while the attack on extractive was considerably less. The carbohydrates of sulphite cook are subjected to several changes and the most important reaction of which is acid hydrolysis of the glycosidic bonds. The extent of carbohydrate decomposition is largely controlled by three factors, viz. time, temperature and acidity. On increasing the pH of the cooking liquor, and thereby bi-sulphite ion concentration, more favourable conditions for the preservation of acid sensitive carbohydrates are secured. Therefore, significantly higher yields at certain degree of delignification are secured on increasing the combined SO\(_2\) charge from the normal level\(^7\) 8-80.
Organic Catalysis for High Yield Pulping

Recently, trials have confirmed the benefits to be gained by employing the organic catalysts in digester. Various quinones and a-mines have been tried to accelerate the delignification with stabilisation in carbohydrate fraction. The cost and availability of the catalyst could prove limiting factors. Acceptance of anthraquino-s (AQ) as an attractive means of improving pulping economics has been faster than is typical in the paper industry.

CIL Laboratory results showed that 0.05% AQ increased the yield of softwood pulp by 2-3%. At this time there are about 10 companies in the world which are operating AQ pulp mills. In Japan, AQ producer Kawasaki Kasei chemicals has patented and commercialised its technology concurrently with CIL.

Holton has predicted that one of the optimum ways of using AQ will be to reduce a combination of the M factor as well as the alkalinity in order to control its effects. A 10-15% reduction in the amount of active alkalinity or in M factor is possible at standard AQ application rate. AQ can and will be used in many different ways and as Holton says, "The reasons choosen by actual mills will be as unique as the mills themselves."

AQ is only effective in alkaline pulping where it accelerates delignification and also improves pulp yield by 2.5-4%. Laboratory results indicate that larger reductions in alkali charge be made and that use of yield gains of as much as 2-3% on wood at constant Kappa number for pine chips. Ghosh et al
reported that addition of small amounts of AQ resulted in significant increase in the delignification and pulp yield, and reduction of rejects without significant losses in strength for hardwoods. Virkola et al. presented the details of neutral sulphite AQ pulping, then its potential application. The alkaline liquor consists mostly of Na₂SO₃ plus some Na₂CO₃ and NaOH, the apparent optimum Na₂SO₃ proportion being 80-85% of the total alkali. Light coloured unbleached softwood pulp is achieved with a big yield advantage over conventional kraft pulp (7-10% points higher than total yield at 40 Kappa number).

The yield gain is primarily due to better retention of hemicellulose. AQ pulp at about 80 Kappa, is about 19% points higher yield than that kraft’s method. With maritime pine, Alcaper provides 2% higher yield than kraft at 30 Kappa number adopting a new technique by combining the catalytic effect of anthraquinone and the delignifying capability of hydrogen peroxide into a single process.

**PROBLEM TAKEN AND WORK DONE**

The paper industry in India is almost 100 years old and is primarily dependent upon forest based raw materials. The present capacity for making paper and board is 12.89 lakh tonnes and for newsprint it is 2.30 lakh tonnes. To keep pace with the increase in literacy, industrial progress and growing population, it is essential that a capacity of 42.50 lakh tonnes of paper and board and 12.89 lakh tonnes of newsprint would be required to be created by the turn of this century. Based on
80% capacity utilisation, production of 34 lakh tonnes of paper and board and 10.31 lakh tonnes of newsprint may be expected, which would meet the anticipated demand by 2000 A.D. In the coming 15 years, therefore, further installed capacity for 24.50 lakh tonnes of paper and board and 10.59 lakh tonnes of newsprint will have to be created. This would mean an additional actual production of 19.00 lakh tonnes of paper and board and 8.40 lakh tonnes of newsprint by 2000 A.D.

It is considered possible that 30% of this production would be based on agro-waste, waste paper and other unconventional fibres. Thus 13.70 lakh tonnes of additional paper and board and 5.30 lakh tonnes of newsprint will be fully dependent upon forest based raw materials. Conventional raw materials being bamboo and woods, an additional 38 lakh air dry tonnes of these for paper and board (bamboo 3 lakh and wood 35 lakh tonnes) and 11 lakh tonnes for newsprint (bamboo 1.60 lakh and wood 9.30 lakh tonnes), will be needed. This is equivalent to 80 lakh tonnes of pulp wood with bark and moisture and 5.50 lakh tonnes of bamboo with moisture. Today paper industry in India consumes only 2% of total wood and 51% of total bamboo.

In the absence of planned programmes of plantation commensurate with the depletion, the forest wealth of the country is fast dwindling. If the national objective of meeting the full demand for paper, board and newsprint, indigenously is to be achieved ensuring, at the same time, a balanced eco system and healthy environment, urgent measures to increase growth and availability of forest based raw materials will have to be undertaken. Thus plantation of proper species has become the
need of the hour.

The choice of the plant species to be raised should necessarily depend on such woods which are fast growing, easy in debarking and chipping and give high yield good quality pulp at comparable optimum cost. As a measure of cost saving, selection of good coppicers having vigour to coppice for several rotations should be preferred to avoid repeated planting expenses. In this contest *Leucaena leucocephala* (Lam.) de Wit, commonly known as subabul in India and ipil-ipil in Phillipines has emerged as a wonder tree. *L. leucocephala* is an exotic plant from Tropical American countries and is also known as *L. leucophylla* (L.) W.T. Gillis, *L. glauca* (Willd.) Benth.\(^91\), and *L. salvadorensis* Standley.\(^92\) It is a tropical leguminous tree species belonging to the group that includes *Mimosa*, *Albizia* and *Prosopis*. Its rate of growth is fantastic\(^93\) and its ability to fix nitrogen\(^94\)–\(^95\) in its root nodules makes it one of the highest yielding, high quality legumes. Its foliage is an excellent fodder with 24% protein and 60% digestability\(^96\)–\(^97\).

Accessions of *L. leucocephala* are grouped into three types. Among them Hawaiian is the most common, dwarf type, grows slow and flowers 3–4 times in a year. It was introduced in India probably more than 100 years ago, as a crop for soil reclamation. Other two types are Salvador, fast growing, arbo- rial type popularly known as the 'Giant' or Hawaiian Giant and Peru type an intermediate between Salvador and Hawaiian, with basal branching habit. Salvador is the most useful type for
LEUCAENA LEUCOCEPHALA (Lam.) de Wit.
(4 YEARS OLD TREE)
energy plantation and includes all the important accessions designated by James Brewbaker as K8, k28, k29, k67 and k636 etc.

Much of the studies on giant *L. leucocephala* has been concentrated on the utilisation of leaves for forms 99-100, varietal variation 101 and yield trials 102-104. Detailed studies have not been conducted on the utilisation aspect of the wood, although preliminary studies have shown that the giant *L. leucocephala* is good for lumber, pulp and paper manufacture, charcoal production and many other purposes 105.

The pulp obtained from kraft process (Sulphate pulping) gave the pulp yield from 47.9% to 50% and kappa number in the range of 21.4 to 28.0. The paper characteristics of pulps were reported to be adequate for manufacturing of corrugated board and paper 106, 107.

Neutral sulphate semichemical cooking and bisulphite pulping of *L. leucocephala* gave high yield in the range of 70.6% to 74.3%. The strength properties of the pulps were good except for tearing resistance 108.

Chemi-thermochemical pulping of *L. leucocephala* with NaOH - Na₂SO₃ has revealed that increasing the amount of NaOH markedly improved the strength of the pulp and reduced the refining energy (RF) but decreased brightness, whereas increasing the amount of Na₂SO₃ slightly increased RF and improved strength and brightness. The optimum percentage of NaOH and Na₂SO₃ has been reported as 1.6 - 2.0% and 0.8 - 1.0% 109.
As this species is exotic, it will have to be grown for pulp manufacture. The present investigations by the author are directed towards the study of the chemical nature of the wood of *L. leucocephala* and exploring the suitability for pulp and paper manufacture, and to get best results for each variable, and to find out suitable age for the cutting cycle of the tree. For this the investigations were carried out on the tree of different ages viz. 3 years, 4 years, 5 years and 6 years. On the basis of present investigations it can be concluded that wood and growth characteristics should be closely considered in conjunction with pulping properties when reformation programmes are undertaken.

During study of *L. leucocephala* plant it was observed that it produces huge quantity of seeds, looking to its wild growth and abundance, a study on fixed oil and proteins from seeds was also undertaken.

The findings have been described in 4 chapters, a summary of these is as follows:

I. **Physico-Chemical Analysis of the Wood of Leucaena leucocephala**

Changes in the physical and chemical properties of the wood of 3 years, 4 years, 5 years and 6 years old trees have been studied. Basic density of the wood was found to increase with the age. It had increased from 0.51 g/cm³ for 3 years wood to 0.60 g/cm³ for 6 years wood sample. Ash was found to decrease a little from 0.80% to 0.72% from 3 years to 6 years wood sample. With ageing of wood solubilities viz. cold water...
solubility, hot water solubility, alcohol benzene solubility and 1% NaOH solubility were found to increase. Similarly lignin had also increased from 22.37% for 3 years wood to 25.96% for 6 years old wood sample. This increase in solubility and lignin content was probably due to increase in the heartwood content of the tree with age. On the other hand holocellulose decreased from 73.41% for 3 years wood sample to 68.92% for 6 years old wood sample. No appreciable change in the alpha cellulose, beta cellulose and gamma cellulose values was observed. Pentosans were observed to decrease with ageing. The acetyl value remained unaffected with the age but the methoxyl value was found to increase a little.

Fibre dimensions remained comparatively unaffected with the variation in age. The result of investigations on the physico-chemical analysis of the most favourable 4 years old wood sample are basic density (0.54 g/cm³), bulk density (0.212 g/cm³), ash (0.77%), cold water solubility (1.08%), hot water solubility (2.35%), alcohol-benzene (1 : 2) solubility (1.78%), 1% NaOH solubility (14.12%), lignin (23.14%), holocellulose (72.56%), alpha cellulose (43.49%), beta cellulose (12.43%), gamma cellulose (17.44%), pentosans (17%), acetyl value (2.49%) and methoxyl value (3.25%). Fibre dimensions were found as: fibre length (1.16 mm), fibre diameter (0.0210 mm), slenderness ratio (55), lumen width (0.0138 mm), cell wall thickness (0.0036 mm), Yunkel ratio (0.5217) and shape factor (0.3968).
On comparison of the characteristics of the woods of different ages, the wood of 4 years of age has been found to be most suitable for pulping because from pulp manufacturing point of view, wood species with high holocellulose, but low in lignin, extractives, ash and silica content would be most suitable. Therefore, the crop cycle may be limited to four years where the above parameters and the volume of the wood are within optimum range.

The wood from 4 years old plants of *L. leucocephala* also seems to have comparable potential for proper manufacture to the other common woods like *Dendrocalamus strictus*, *Eucalyptus*, *Rosewellia serrata*, *Geshania grandiflora* in vogue.

II. Semichemical Cold Soda Pulping of *Leucaena leucocephala*:

Semichemical cold soda treatments were carried out on chips of *L. leucocephala* of different age by varying NaOH percentage as 10% and 15% and each at 2 hours and 3 hours cooking time at 11 kg./cm² pressure. After treatment chips were refined at different freeness levels and after washing sheets were made and then tested for brightness and strength properties. Strength properties were measured in terms of burst factor (B F), breaking length (B L), and tear factor (T F). NaOH consumption was also noted for each cook.

It was observed that chemical consumption reduced with the increase in age of the wood for each cook. The results reveal that strength properties decrease with the increase in age. This may be due to increase in density of wood with age.
causing difficult penetration of NaOH in chips and subsequently less softening of chips and difficult fibreisation during refining. The experiments revealed that by increasing the chemical consumption, the strength properties had also increased, but the pulp yield had gone down a little. It was also observed that brightness of unbleached pulp decreased with the age from 38.4% ISO to 29.8% ISO. This may be due to increase in lignin and solubilities of wood with age. Brightness was also found to decrease with increase in chemical consumption.

Effect of treatment parameters on carbohydrate composition revealed that neither the alpha cellulose, nor the lignin content of the pulp, apparently, was affected. But the hemicellulose were found to be attacked by increase in alkali charge.

Wood of 4 years age was found to be suitable for pulping with 10% NaOH impregnation for 2 hours at 11 kg/cm² pressure. Brightness of this pulp was 38.4% ISO at chemical consumption 6.65% and pulp yield was 86.2%. Longer fibre fraction (+28 and +48) was 55.5% and fines were 23.5%. Strength properties in terms of B F, B L, T F, and porosity at 200 GSF were 21.5, 4175 meters, 50.1 and 25.1 second respectively.

Single stage hypochlorite bleaching was carried out on cold soda pulps by varying the percentage of hypochlorite as 5%, 7.5%, 10% and 12.5% as available chlorine. It was observed that in all cases brightness had increased approximately by 24%, 36%, 46% and 51% respectively of the initial unbleached pulp brightness. In case of 3 years and 4 years old wood, brightness
of 50% ISO could be achieved by bleaching with 7.5% hypochlorite and for 5 years and 6 years old wood it could be achieved by 10% and 12.5% hypochlorite respectively. Bleaching losses were in the range of 2 to 4%. Strength properties after bleaching were found to increase a little.

Cold soda process pulp of *L. leucocephala* was blended with different pulps in various proportions for getting a good newsprint furnish and it was found that it could be made by blending 33.3% each of *L. leucocephala* cold soda pulp, Bamboo chemical pulp and *Salai* groundwood mechanical pulp. A more suitable furnish could be obtained by blending the above mention pulps in the proportions of 45%, 25% and 30% respectively.

III. Sulphate Chemical Pulping and Anthraquinone Sulphate Chemical Pulping of *Leucaena leucocephala*:

Sulphate chemical pulping or kraft pulping system for *L. leucocephala* was studied in detail with a view to optimise pulping operations. Cooking trials with anthraquinone (AQ)- catalysed sulphate chemical cooking was also investigated to find out the economy of AQ addition in sulphate pulping liquor.

The heat energy input to the pulping process was measured in terms of H-factor and the chemical energy input to the pulping was measured in terms of active alkali defined as NaOH + Na₂SO₃. However, sulphidity and liquor to wood ratio was kept constant at 18% and 3.5 : 1 respectively. The extent of delignification or bleachability of the pulp was measured in terms of permangnate number (KNO₅) which was found to be correlated with
yield of pulp in percentage based on oven dry weight of chips.

To optimise the active alkali charge for the pulping, its doses of 12%, 14% and 16% were charged. Drop in total yield and permanganate number was observed with the increase in active alkali charge. It was observed that optimum quality of pulp with permanganate number 20.5 and total pulp yield of 53.1% with less reject percentage of only 0.4% could be obtained by cooking with 14% active alkali charge.

In the above mentioned cook the H - factor was 1457. Keeping the other cooking conditions same when H- factor was increased to 1761, the yield drop of 1.2% was found and permanganate number reduced to 16.8. This showed that cellulose became susceptible to degradation by increasing H - factor.

Pulp classification was done at initial freeness of about 650 ml CSF and second at around 350 ml CSF. It was observed that longer fraction decreased and fines increased with increase in active alkali charge and H- factor. Strength were measured in terms of burst factor (BF), breaking length (BL) and tear factor (TF). These were observed to decrease a little with increase in active alkali charge and H - factor. This shows that cellulose degradation takes place after an optimum limit of pulping condition. Thus, from the consideration of yield, permanganate number and strength properties of pulp, active alkali charge of 14%, at H- factor 1457 with sulfidity 18% and liquor to wood ratio 3.5 : 1 was found to be optimum conditions of pulping. BF, BL and TF of the pulp obtained in above cook were in the order of 50.75, 6880 meters and 98.1 respectively at 350 ml CSF.
Pulping experiment under above conditions were carried out with wood with bark and it was also found suitable for pulping.

Bleaching of the above two pulps was done with 10% chlorine in three stages of chlorination, alkali extraction and hypochlorite (C/E/H) sequence. Brightness of 70% ISO and 67.5% ISO could be achieved for the two pulps respectively. Viscosity of the bleached pulps was found to be 11.5 and 11.8 cp (0.5% CED solution). A slight loss in the strength properties was observed in bleaching process which shows the little degradation of cellulose during bleaching.

The study of anthraquinone (AQ) sulphate pulping was done on this wood with 0.05% AQ addition and varying the active alkali charge and H-factor. It was found that a possible reduction of 1.9% in active alkali with 1.8% gain in pulp yield could be achieved by using 0.05% AQ without any adverse effect on the pulp bleachability and other properties. Similarly, H-factor could be brought down from 1457 to 960 with simultaneous pulp yield gain of 1.4% by using 0.05% AQ.

IV. Chemical Studies on the Fixed Oil and Seed Protein of Leucaena leucocephala:

Seeds of *L. leucocephala* have been analysed for fatty acid composition of its fixed oil and protein. The studies are important, as a comparatively new polarographic method (electro-chemical method has been successfully applied for the qualitative as well as quantitative analysis of fatty acids present in the fixed oil. Similarly, the amino acids obtained from the
proteins hydrolysate of *L. leucocephala* have been quantitatively analysed polarographically by recording the catalytic hydrogen wave produced at the D M E by each amino acid.

(A) **Fatty Acids of *L. leucocephala***

Saturated fatty acids with E\(^{1/2}\) values - 0.46 V Vs S.C.E, - 0.60 V Vs S.C.E, 0.70 V Vs S.C.E, - 0.74 Vs S.C.E, and - 0.82 V Vs S.C.E, corresponded to myristic acid (0.89%), palmitic acid (12.91%), stearic acid (5.49%), arachidic acid (1.60%) and behenic acid (1.18%) respectively.

The unsaturated fatty acids with E\(^{1/2}\) values - 0.1 V Vs S.C.E, - 0.30 V Vs S.C.E, - 0.48 V Vs S.C.E, and - 0.64 V Vs S.C.E, indicated the presence of linolenic acid (0.99%), linoleic acid (55.15%), oleic acid (20.63%), palmitoleic acid (0.90%) respectively.

The oil in the seed was 7.2% and it can be tried in paints due to its high percentage of unsaturated acids.

(B) **Amino Acids from the Seeds***

The seeds of *L. leucocephala* contained 24.70% of protein. Amino acids obtained from the protein hydrolysate have been characterised as cystin (11.5%), serine (8.0%), arginine (13.05%), glycine (13.05%) alanine (22.1%) methionine (13.05%) and phenylalanine (19.2%), with E\(^{1/2}\) values - 0.66 V Vs S.C.E, - 0.68 V Vs S.C.E, - 0.72 V Vs S.C.E, - 0.90 V Vs S.C.E, - 0.76 V Vs S.C.E, 0.54 V Vs S.C.E and - 0.72 V Vs S.C.E, respectively.

The results obtained by polarographic analysis are in agreement with those obtained with paper chromatography and colorimetry suggesting the utility of this electrochemical technique in the analysis of natural products.
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