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DEPARTIMENT OF CHEMICAL ENGINEERING

PROJECT ON PRODUCTION OF PULP FROM EUCALYPTUS TREE PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE BACHELOR OF SCIENCE DEGREE IN CHEMICAL ENGINEERING (PROCESS)

PULP PRODUCTION FROM EUCALYPTUS TREE

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PULP PRODUCTION FROM EUCALYPTUS TREE

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DECLARATION

We, the undersigned, declare that this project is our original work, has not been presented for a degree in any other university and that all sources of material used for the project are duly acknowledged.

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ABSTRACT

Wood is the primary raw material used to manufacture pulp and paper. So, depending on some criteria we chose eucalyptus tree. These raw materials are available in our country, can produce fiber or cellulose for pulp and paper industries under relatively short rotation; can grow adequately in a wide range of ecological conditions, of Ethiopia.

The general objective of this project was to produce pulp from eucalyptus tree. In this project we have done three Experiments. The first experiment was done as for comparison of the two basic pulping methods i.e. Kraft and soda pulping. In the second experiment we have done four trials based on Kraft pulping only. When we compare the two processes (i.e.) Soda and Kraft) though Soda process requires only one chemical but in large amounts and take many time and energy to effectively break the lignin bonds. Kraft process requires fewer amounts of different chemicals and also helps in complete lignin molecule breakage. From this we can conclude that Kraft process is more advantageous. We try do material and energy balance at laboratory level and Industrial level, material sizing and to evaluate techno economic feasibility of pulp production from eucalyptus tree.

KEYWORDS: pulp, eucalyptus tree stem, Kraft process or soda process, blea

Table of Contents

List of Table

List of Figure

LIST OF ACRONYMS

ECF – Element chlorine free

TCF – total chlorine free

Cp- Specific heat capacity

Q- Amount of heat needed

FCI- Fixed capital investment

TCI- Total capital investment

DC- Direct cost

IC- Indirect cost

WCI- Working capital investment

TPC - Total production cost

FC – Fixed charge

TFC- Total fixed charge

DPC- Direct production cost

OL- Operational labor

POC- Plant overhead cost

PEC- Purchasing equipment cost

NP- Net profit

ROI- Return on investment

DEP- Depreciation

PBP- Payback period

IFC- International Fund Company

M.C- Moisture content

CHAPTER ONE

1. BACKGROUND

1.1 INTRODUCTION

Pulp was first made in China around 105 AD. The technology was practiced solely in China for the subsequent 500 years, and then spread to Japan in 610 AD, and later into Central Asia. It appeared in Egypt about AD 800 AD, but was not manufactured there for another 100 years. A variety of raw materials were used and these included mulberry bark, old rags and hemp. Pulp and paper was introduced to Europe by the Moors on their invasion of the Iberian Peninsula, and the first mills were established in Spain in about 1150. The craft then spread into most of the rest of Europe during the next two centuries. The development of printing technology in the 15th century saw the start of the widespread publication of books and this greatly stimulated the pulp and papermaking industry. The first paper mill in England was established in 1495, and the first such mill in North America in 1690. A crisis arose in the early 19th century as raw material for paper production was in shortage. European paper makers had grown used to using rags for paper manufacture and the shortage forced manufacturers to seek alternative raw materials. This gave rise to the use of wood for paper manufacture. [1]

In Ethiopia pulp is not produced but it is imported. Ethiopian pulp and papers Share Company was one of the first paper manufacturing companies which was established and gets legal recognition in August 29, 1963G.C. The shareholders of this company were ministry of finance, Ethiopian Development Bank, Ethiopian Investment Bank and Panser and Witmor Company with a beginning capital of 50,000 birr. When it started production in 1970G.C the total expenses were 22 million birr and at the same time its capital was increased to 10 million birr. Currently the shareholders of the company are Ethiopian government 70% and IFC 30%. During its establishment the company produces paper product of 25 ton daily and 8,500 ton annually. But in 1989 it has increased its production capacity to 10,000 ton/annually [2].

Pulp and paper are manufactured from raw materials containing cellulose fibers generally Wood, recycled paper, and agricultural residues. Hard wood such like Eucalypt is a fast growing tree nwhose wood is the main raw material for paper pulp production in Southwest Europe, Brazil, South Africa, and other countries. Different eucalypt species are used for pulp and paper making, including Eucalyptus globulus, E. nitens, E. maidenii, E. dunni, E. grandis, E. urophylla and E.

saligna, and single, double and triple crossings hybrids among these species. So our aim is to produce pulp from eucalyptus trees [3].

The purpose of pulping is to extract cellulose fibers from plant material, generally hardwood, softwood trees or non-wood plant for paper making. The most abundant component of the native wood matrix is cellulose, a polysaccharide that is desired for paper production. The second most abundant component of native wood is lignin, a complex polymer made of aromatic units. Two approaches have been employed to pulping and they are chemical pulping and mechanical pulping. Mechanical pulping involves the use of mechanical force to separate the wood fibers but chemical pulping dissolves lignin from cellulose and hemicellulose fibers by using chemicals. Chemical pulping, dissolving the lignin in the raw material used to create pulp, is the most commonly used pulping process. The three main types of chemical pulping are the more common sulfate pulping (most commonly known as Kraft pulping), sulfite pulping and soda pulping [4].

1.2. Statement of the problem

Pulp is not produced in Ethiopia, so Paper Industry in the country import paper raw material from other country. Ethiopia is not producing its pulp and mostly the paper industries depend on imported pulp or recycled paper. There are critical limitations of knowledge in synthesizing pulp and paper from wood-based cellulose resources; Ethiopia pulp and paper Share Company produce 10,000 ton of paper and 11470 ton of carton box by importing pulp from other country yearly. This causes the high price of paper in country since the demand increases from day to day, and the cost of taxation is also high. The eucalyptus tree can produce fiber for pulp and paper industries under relatively short rotation. It can grow adequately in a wide range of Ecological conditions and sites in our Country Ethiopia. This raw material is available in our country especially in Oromia region, Amhara region, Tigrai region, SNNP Region and in all other region of country except some desert area of the country. Producing pulp from eucalyptus tree solve the shortage of this raw material, reduce cost of raw material and it’s transportation, reduce foreign taxation and Reduce time of production.

1.3. Objectives

1.3.1. General objective

The General objective of this project was to produce pulp from eucalyptus tree.

1.3.2. Specific objectives

The specific objectives of the study will be

- To produce pulp using Kraft and soda methods in laboratory scale
- To analyze the results obtained in the processes and to propose the better process based on yield, time, and consumption of raw material and energy.
- To characterize the parameters that expresses the quality of the pulp.
- To study the feasibility of the pulp production from eucalyptus tree

1.4. Significance of study

This project will contribute significantly to produce pulp of good quality from eucalyptus tree within the country by replacing pulp imported from abroad. Eucalyptus tree is easily available in our country and high content of cellulose fiber.

Some of its significance

- Show the direction for researcher and student to study more about pulp and it's production process from different raw material in the country.
- Interesting the investor's to make investment on pulp and paper industry.
- Market opportunities for those their life is depend on raw material growing (farmers) like eucalyptus tree.
- Knowledge and Technology transformation for citizens.
- Contributes to the economic development activity of country.
- It can be used as an alternative raw material for producer of paper in Ethiopia.
- Create job opportunity for citizens.
- Increase the culture of planting tree and use it.

1.5. Scope of the study

In this work production methodology, be studied for pulp and paper production from eucalyptus tree. The project observe experimental designs conducted in laboratory scale to determine how eucalyptus tree can be used for the purpose of pulp and paper and address the yield of pulp obtained from those different methodologies. The study would review how economic and environmental problems associated with pulp and paper productions can be solved and how production of pulp and paper would be scaled up into large industrial scale to meet specific requirement of paper pulp.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Over view of pulp production.

Pulp is a fibrous material resulting from complex manufacturing processes that involve the chemical and/or mechanical treatment of various types of plant material. Today, wood provides the basis for approximately 90% of global pulp production, while the remaining 10% originates from annual plants. Pulp is one of the most abundant raw materials worldwide which is used predominantly as a major component in the manufacture of paper and paperboard. A pulp mill is a manufacturing facility that converts wood chips or other plant fiber source into a thick fibber board which can be shipped to a paper mill for further processing. Pulp can be manufactured using mechanical, semi-chemical or fully chemical methods (Kraft, Soda and Sulphite processes). The finished product may be either bleached or non-bleached, depending on the customer requirements. Wood and other plant materials like used to make pulp contain three main components: cellulose fibers (desired for papermaking), lignin (a three dimensional polymer that binds the cellulose fibers together) and hemicelluloses, (shorter branched carbohydrate polymers). The aim of pulping is to break down the bulk structure of the fiber source, be it chips, stems or other plant parts, into the constituent fibers [5].

As try to describe above wood pulps are categorized by the pulping process as either chemical or mechanical pulps, reflecting the different ways of fiberizing. Chemical pulping dissolves the lignin and other materials of the inter-fiber matrix material, and also most of the lignin which is in the fiber walls. This enables the fibers to bond together in the papermaking process by hydrogen bond formation between their cellulosic surfaces. As noted previously, Kraft pulping has developed as the dominating cooking process, and today the Kraft pulps account for 89% of the chemical pulps and for over 62% of all virgin fiber material. In 2000, the annual global virgin pulp fiber production total 187 million tons while only about 50 million tones 27% accounted for market pulp. The remaining 73% stems from integrated paper and cellulose converting mills (captive use) [6]

Table 2.1 Global pulp production by category, by 2010

Pulp category	Pulp production [Mio t]
Chemical	131.2
Kraft	117
Semi chemical	7
Mechanical	7.2
Non wood	37.8
Recovered fiber	147
Total fiber	334

(source Herbert holic,hand book pulp and paper ,volume one)

Chemical pulping achieves this by degrading the lignin and hemicelluloses into small, water soluble molecules which can be washed away from the cellulose fibers without depolymerizing the cellulose fibers (chemically depolymerizing the cellulose weakens the fibers). Eucalyptus wood is the increasingly dominating source of short fibers for the pulp and paper industry worldwide particularly; plantation eucalypt species are the dominant raw materials for bleached hardwood Kraft pulp production [7].

2.2. Raw materials for pulp production

Good availability and Process ability the distribution and morphology of the cell types and the Chemical composition are criteria’s to select raw material for pulp. Wood is the principal source of cellulosic fiber for pulp and paper manufacture –93%.There are two types of wood: soft wood and hard wood. The difference between softwood and hard wood is with respect to weight and volume percentages of the various types of fiber cells, another major difference is the length of the fibers. The other sources of row materials are Non-woods such as bagasse, cereal straws, bamboo. The cellulose content as well as the amount of lignin and its structure determines the pulp yield and the conditions to be used for digestion [8].

2.3. Chemical composition of wood

Wood is an organic material that contains carbon. With very little variation between different species, woody matter is composed of the three main elements carbon, oxygen, and hydrogen (Tab. 2.2). Nitrogen as well as some inorganic elements, such as sodium, potassium, calcium, magnesium, and silicon, is also essential material compounds that are mostly involved in the metabolism of the living cells during wood formation and growth [9].

Table2.2 Elementary composition of wood

Element(s)	Contents	
Carbon	C	49
Oxygen	O2	44
Hydrogen	H2	6
Nitrogen	N2	<1
Inorganic element	Na, K, Ca, Mg, Si	<<1

(Source: Haygreen J.G., Bowyer J.L. 1982: Forest products and wood science. Iowa State University Press).

At a higher level, these elements form macro molecule that is called polymers. Which represents the main cell wall compounds of cellulose, hemicelluloses and lignin; These are the main constituents of all wood species. To a lesser extent, low molecular-weight substances (e.g., extractives and inorganic substances (ash) can also be found, and these are representative of individual plant. The proportions and chemical composition of lignin and hemicelluloses differ in softwoods and hardwoods, while cellulose is a relatively uniform component of all woods. In wood from temperate zones, the portions of the high-polymeric compounds which constitute the cell wall account for 97-99% of the woody material. For tropical woods, this value may decrease to an average of 90%, with 65-75% of the woody material consisting of polysaccharides [10]

- **Cellulose**: The cellulose present in wood is mostly in the form of fibers. The cellulose fibers are obtained as pulp after pulping process. Cellulose fiber is a long chain of single monomer C6H10O5. A carbohydrate composed of C, H2, and O2, Determine the character of fiber, Polymer of glucose and Insoluble in water

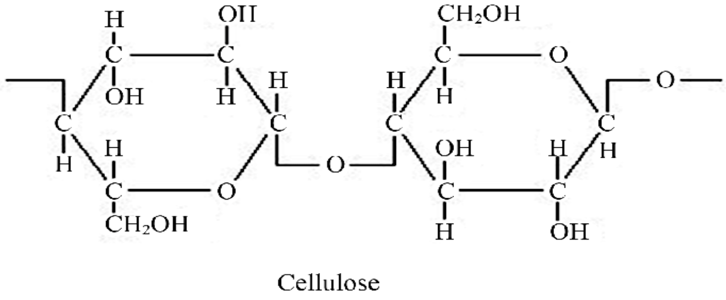

Figure 2.1 cellulose structure

Hemicelluloses: Hemi cellulose is made of two compounds, namely Pentosans and Hexosans. The former is responsible for the grease proof properties imparted in the paper. Polymer of five sugars and more dissolved than cellulose.

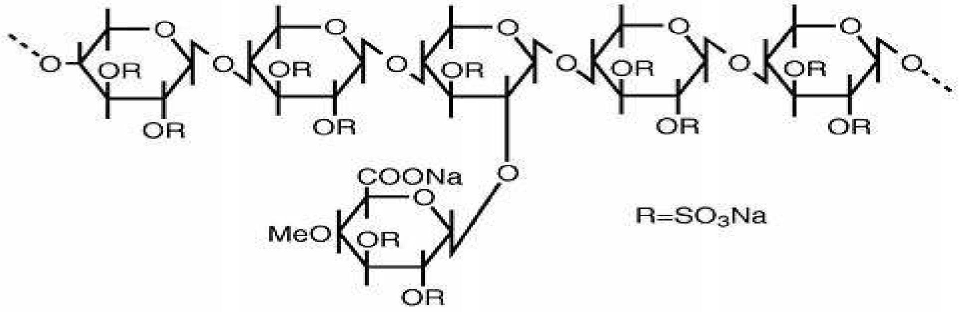

Figure 1 .2 hemicellulose structure

- **Lignin**: The main component of wood that needs to be removed to turn it into paper is a compound known as lignin. This name refers to a group of chemicals that are essentially three dimensional polymers of trans-coniferol, trans-sinapol and trans-p-coumarol, along with hemicelluloses and aromatic carboxylic acids. Lignin is the reinforcing compound that is deposited on tree cell walls to make the wood strong enough to carry the weight of the tree crown. However, it is also the compound that makes wood pulp brown, so it is removed from all wood pulp except that used to make brown paper and some cardboard,

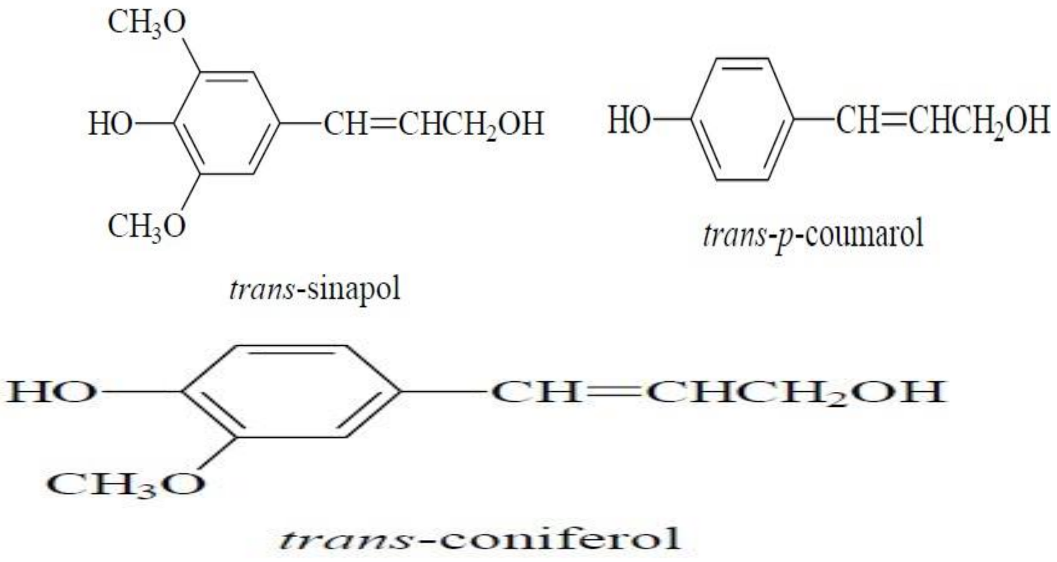

Figure2.2 lignin structure

2.4. Selection criteria

Eucalyptus tree is one example of hard wood and more cellulose fiber content than soft wood. It will be selected by us as a raw material for the reason eucalyptus tree can produce High amount of fiber relative to other soft wood and Non wood for pulp and paper industries under relatively short rotation, Can grow adequately in a wide range of ecological conditions, and also easily available in our country.

Currently, it is estimated that, over 500000 ha of the land is covered by Eucalyptus plantation in Ethiopia Eucalyptus can be cultivated with minimum management activities for different products and services. (11)

Table2.3 shows cellulose and lignin composition of wood and non-wood

Material	List of material	Cellulose(%)	Ligning(%)
Wood	Coniferous	40-50	26-34
	Deciduous	38-49	23-30
Non wood	Rice stalk	28-48	12-16
	Banana stem	32-45	15-16
	Wheat straw	29-51	16-21
	Barley stalk	31-45	14-15
	Kenaf Bast	44-57	15-19

(Source: Lakhansingh and Dr.TarunKanti Bandyopadhyay,2013)

2.5. Chemical composition of eucalyptus wood

The typical chemical composition of E. globules wood in relation to some other hardwood species is presented in Table below. Among the presented eucalypt species, E. globulus contains clearly the lowest amounts of lignin, extractives and ashes. At the same time the amounts of cellulose and hemicelluloses, expressed as pentosans, are higher in E. globulus than in E. grandis and E. urograndis woods. For the pentosanes content E. globulus wood is inferior only to Betula pendula(1)

Table 2.4 Chemical composition of E. globulus and Some other hardwoods(%, w/w).

Types	E. Globulus	E. Urograntdis	E. Grandis	B. Pendula	A. Mangium
Liginin	20.5	26.7	25.7	20.4	27.1
Cellulose	50	48.6	46.6	45.3	46.5
Pentonsans	14.1	11.3	13.5	18.1	13.3
Extractives	1.72	1.91	2.1	2.24	4.46
Ashes	0.17	0.53	0.25	49	0.22

(Source: Gutiérrez, A., del Río, J.C., Gonzalez-Vila, F.J., Martin, F., 1999. Chemical composition of lipophilic extractives from Eucalyptus globules Labill. Wood. Holzforschung 53, 481–486)

2.6. Type of Pulping production process

The pulping process is the separation of cellulose fibers from wood and non-wood feed stock. The pulping process is divided into three categories namely:

1. Mechanical pulping
2. Semi-chemical pulping
3. Chemical pulping.

2.6.1. Mechanical pulping

Pulping by mechanical energy (small amount of chemicals and heat), Among the total amount of paper pulp produced in the world, mechanical pulp accounts for about 20%. Although mechanical pulping is a thermo mechanical process, chemical processes may also play a certain role. The mechanical defibration of wood is carried out in two different ways, namely as a grinding process or as a refining process. Wood and agro-residues are exposed to grinding or shredding to free the cellulose fibers. This process produces high pulp yield i.e. of the order of 90-95%. Lignin is retained with pulp in this process. Pulp produced in this process is normally used for newsprint production. There are different types of mechanical pulping processes as briefly listed below (3).

- Stone ground wood pulping: Wood logs of 1-1.5 m length are fed into the grinder and forced mechanically against the grinding stone to extract the pulp.
- Refiner mechanical pulping: The fiber separation is done in disc refiner.

- Thermo mechanical pulping: Wood chips are softened in a pre-heater and then refined in a disc refiner to extract pulp.

Disadvantages

- ✓ Fibers are easily damaged
- ✓ Relatively low-cost pulp
- ✓ Pulp unsuitable for many uses because of the present of lignin .
- ✓ Low strength and relatively poor surface quality paper
- ✓ Short-term durability

2.6.2. Semi-chemical pulping

Semi-chemical pulping techniques use weak chemical solutions composed of sodium sulfite (Na_2SO3) and sodium carbonate (Na_2CO3) to help digest the lignin in the pulp. In addition to the chemical solutions, mechanical refining is used to separate the fibers (13).

2.6.3. Chemical pulping

Chemical pulping is a process of extraction of cellulose fibers present in wood-based or Non wood-based stock by freeing the lignin content in the media of chemical solution preferably at elevated temperature and pressure and it is called cooking process. Lignin acts as a bonding agent to the cellulose fibers. In this process, the pulp yield is around 50% and most of the (~ 95%) lignin present in the wood is dissolved by the chemical solution. In chemical pulping, the fibers are less likely to be damaged than in other pulping processes. Chemical pulping is more expensive than mechanical pulping but it has better strength and brightness properties. In Chemical pulping process, extracted fibers are washed, filtered and sent to the paper making process. The filtrate, separated out in the cooking process, is called black liquor which is further processed in a recovery boiler for recovering inorganic chemicals and organics in the form of heat energy. Chemical pulping can be produced by three methods i.e, Soda pulping, Kraft or Sulfate pulping and Sulfite pulping (14).

A) Kraft process

The Kraft process (also known as Kraft pulping or sulphate process) is a process for conversion of wood into wood pulp consisting of almost pure cellulose fibers. It entails treatment of wood chips with a mixture of sodium hydroxide and sodium sulphide, known as white liquor, which breaks the bonds that link lignin to the cellulose. The Kraft process is the dominant chemical pulping method (3).

B) Soda process:

This pulping process is entirely similar to Kraft's process. The only difference exists is the cooking chemicals used. In soda pulping process only NaOH or combination of NaOH and Na_2CO_3 are used. The quality of pulp obtained in soda pulping is low and used for manufacturing low grade paper. (3)

C) Sulphite process:

In the sulfite process, a mixture of sulphurous acid (H_2SO_3) bisulfite ion (HSO_3) is used to attack and solubilizes the lignin. The sulphites combine with the lignin to form salts of lingo sulfonic acid which are soluble in the cooking liquor, and the chemical structure of the lignin is left largely intact. The chemical base for the bisulfite can be ionic calcium, magnesium sodium or ammonium. Sulphite pulping can be carried out over a wide range of P_H. "Acid sulphite" denotes pulping with an excess of free sulfurous acid (p_H 1-2),while "bisulfite" cooks are carried out under less acid conditions (p_H 3-5).

Sulfite pulps are light in color than Kraft pulps and can be bleached more easily, but the paper sheets are weaker than equivalent Kraft sheets. The sulphite process works well for such soft woods as spruce, fir and hemlock, and for such hardwoods are more difficult to handle. This sensitivity to wood species, along with weaker strength and the greater difficulty in chemical recovery are the major reasons for the decline of sulphite pulping relative to Kraft the trend (13).

2.7. The manufacturing process

The process whereby timber is converted into pulp involves seven steps. The first four convert the logs into a mass of cellulose fibers with some residual lignin using a mixture of physical and chemical processes. This pulp is then bleached to remove the remaining lignin and finally spread out into smooth, pressed sheets (often with chemicals added to provide particular properties such as color or water resistance). For some papers (e.g. cardboards and 'brown paper') the bleaching step is unnecessary, but all white and colored papers require bleaching (8).

2.7.1. Reception and storage of wood

Wood may be received as logs directly from the forest or as by-product chips from some other wood working industry like sawmills and plywood mills. Chips are normally free of bark and can be used after screening and possibly washing. The wood is transported to the mills by ship, truck or rail but also to a limited extent by floating logs to the mill site. Where the latter is used, there will be some leaching of resin acids and nutrients while the wood is in contact with water. Mechanical pulping techniques may use either logs or chips but chemical pulping techniques will always use chips [7].

A. Debarking

The debarking of wood subjected to pulping processes is a very important subject; a too high bark content of the chips reduces the brightness, leads to yield reduction and extended cooking times, to increased bleaching chemicals consumption, and finally results in bad pulp properties. The lowest acceptable bark content is required for ground wood logs. In particular, phenolic substances in the outer bark lead to problems in sulphite pulping due to reactions with lignin.(6)

B. Debarking Methods

The most common debarking technologies in forest product industries include:

- Drum debark
- Rotary or cradle debark
- Ring debark

2.7.2. Wood chipping and screening

For chemical pulping processes, the logs are reduced to chips in a chipper. The objective in chipping is to form uniform-sized chips, which will result in a better pulp product. A uniform chip-sized distribution is necessary for the efficiency of the processes and for the quality of the pulp.

After the chipper station, the chips are screened in order to remove oversized chips and fines. Fines can also be cooked together with chips or separately in a sawdust cooker, or they can be burnt or used for other purposes. The screening of chips is not always applied. It depends on the required pulp quality, e.g. screening is not necessary for the manufacturing of unbleached Kraft pulp for packaging paper grades. Oversized chips may go for reprocessing in a crusher or re-chipper. Chips are screened for thickness, as this is a critical parameter both in chemical and mechanical pulping. Often the overall optimum conditions are reached by sacrificing some raw material to secure stable processing conditions, which, in turn, promote better pulp quality and less pollution. The material removed in the screening operation can be sold for other purposes or burnt in a solid fuel boiler with the heat recovery together with bark or/and sludge from the waste water treatment plant.[2]

2.7.3. Cooking

The "cooking process" is where the main part of the delignification takes place. Here the chips are mixed with "white liquor" (a solution of sodium hydroxide and sodium sulphide), heated to increase the reaction rate and then disintegrated into fibres by 'blowing' – subjecting them to a sudden decrease in pressure. Typically some 150 kg of NaOH and 50 kg of $Na_2S$are required per ton of dry wood. This process is, like any chemical reaction, affected by time, temperature and concentration of chemical reactants. Time and temperature can be traded off against each other to a certain extent, but to achieve reasonable cooking times it is necessary to have temperatures of about 150 –165^oC, so pressure cookers are used. However, if the temperature is too high then the chips are De lignified unevenly, so a balance must be achieved (6).

The kinetics of the Kraft pulping is quite well understood, but the reaction is heterogonous and therefore difficult to examine. To determine when to interrupt the cooking, a model relating time, temperature and cooking chemical charge is used. The degree of delignification is the most important parameter for determining pulp quality, and is normally expressed in what is called a "Kappa number". This number is directly related to the amount of lignin still remaining in the cooked pulp (4).

There are two different cooking systems; batch and continuous. In batch cooking, chips and white liquor are charged to a pressure vessel and are then heated with steam to a set temperature for a set time. When the correct delignification has been achieved, the cook is “blown" (the pressure is suddenly released so that the cooked chips disintegrate into fibers. (6)

In the continuous process, chips and white liquor are fed continuously to the top of a tall pressure vessel. The chips move down the 'digester' by gravity (as a plug) to be finally blown from the bottom of the vessel. The cooking time cannot be varied in this case (it is set by the production rate) and only the temperature and the chemical charge can be controlled. Many developments have taken place during the last decade to improve the 'science' of Kraft pulping. The challenge has been to remove as much of the lignin as possible without degrading the cellulose and without losing too much yield. It is now well known that the concentrations of NaOH, Na_2S and dissolved lignin during the various phases of the delignification are of crucial importance for the pulp strength. Generally speaking, it is desirable to have a high sulphide concentration in the beginning of the cook, a low lignin concentration in the liquid phase towards the end of the cook, and an even alkali concentration during most parts of the cook. How to achieve this in practice under conditions of high temperature and high pressures has been a challenge, and much development is still going on [12].

2.7.4. Recovery process

The excess black liquor is at about 15% solids and is concentrated in a multiple effect evaporator. After the first step the black liquor is about 20 - 30% solids. At this concentration the rosin soap rises to the surface and is skimmed off. The collected soap is further processed to tall oil. Removal of the soap improves the evaporation operation of the later effects. The weak black liquor is further evaporated to 65% or even 80% solids ("heavy black liquor") and burned in the recovery boiler to recover the inorganic chemicals for reuse in the pulping process. Higher solids in the concentrated black liquor increases the energy and chemical efficiency of the recovery cycle, but also gives higher viscosity and precipitation of solids (plugging and fouling of equipment) (9).

2.7.5. Pulp washing

Because of the high amounts of chemicals used in the cooking wood in Kraft pulping, the recovery of the chemicals is of crucial importance. The process where the chemicals are separated from the cooked pulp is called pulp washing. A good removal of chemicals (inorganic and organic) is necessary for several reasons.

- ✓ The dissolved chemicals interfere with the downstream processing of the pulp
- ✓ The chemicals are expensive to replace
- ✓ The chemicals (especially the dissolved lignin) are detrimental to the environment

There are many types of machinery used for pulp washing. Most of them rely on displacing the dissolved solids (inorganic and organic) in a pulp mat by hot water, but some use pressing to squeeze out the chemicals with the liquid. An old, but still common method is to use a drum, covered by a wire mesh, which rotates in a diluted suspension of the fibers. The fibers form a mat on the drum, and showers of hot water are then sprayed onto the fiber mat (5).

2.7. 6. Pulp screening

Apart from fibers, the cooked pulp also contains partially uncooked fiber bundles and knots. Modern cooking processes (together with good chip screening to achieve consistent chip thickness) have good control over the delignification and produce less "rejects". Knots and shaves are removed by passing the pulp over pulp screens equipped with fine holes or slots (3).

2.7. 7. Bleaching

Pulp produced by the Kraft process is brown. This presents no problem for certain uses, e.g. for sack paper, most corrugated boxes, some bag paper etc. However, a major proportion of the Kraft pulp that is made is used for white or colored papers such as writing and printing papers, and then the pulp needs to be bleached Bleaching involves removing virtually all of the lignin that still remains after cooking, as the lignin contains the chromophoric groups which make the pulp dark. Strictly speaking, bleaching and cooking are both delignification processes, and modern developments have tended to blur the difference between the two processes (4).

In practice, there are two separate "bleaching" process steps: oxygen delignification and final bleaching. To measure the lignin content in pulp, a number called the "Kappa number" is used. The Kappa number is directly proportional to the lignin content of the pulp. Pulp from the digester has a Kappa number of 20-35 for softwood and 15-20 for hardwood (hardwood contains less lignin and can therefore be cooked to a lower Kappa number). Oxygen delignification removes about half of the lignin remaining after the cooking process, so that the Kappa number of the oxygen de-lignified pulp is typically 12-18 for softwood. The final bleaching removes all remaining lignin and decreases the Kappa number to zero (10).

2.7. 8. Oxygen delignification

In oxygen delignification, washed pulp is treated with a highly alkaline solution of sodium hydroxide. The high pH ionizes phenolic groups in the lignin, which are then attacked by molecular oxygen. The aromatic part of the lignin is partly destroyed and it is then depolymerized to lower molecular weight compounds. These are more soluble in water and can be removed from the fibers. It is important that the pulp has been at least partly washed Beforehand because the black liquor solids in unwashed pulp consume oxygen.

After the oxygen delignification stage, the pulp has to be washed very well, as otherwise the organics carry over to the final bleaching process, consuming chemicals there and also decreasing the environmental benefits. The highly alkaline conditions of oxygen delignification also make carbohydrate fractions in the fibers react with oxygen to a certain extent. As these reactions break down the polymer chains of cellulose, and thus decrease the pulp strength, these reactions must be kept to a minimum. It has been found that it is the radical species of oxygen which are particularly harmful to the carbohydrates (11).

The formation of radicals is promoted by the presence of certain metal ions. However, it has been found that magnesium salts inhibit metal ion activity, and magnesium sulphate is therefore normally added as a protector in oxygen delignification. Oxygen is only sparingly soluble in water, and the controlling factor on the reaction rate is therefore normally the concentration of dissolved oxygen around the fiber. Originally a high pulp consistency (30-40%) was used to overcome this restriction. However, modern high intensity mixers can distribute the oxygen in very small bubbles on the fibers, and these mixers have made it possible to operate at "medium consistency" (10-12%). Medium consistency has several advantages: the equipment is simpler and the risk of fire (because of the use of oxygen) is virtually eliminated. Oxygen delignification can significantly decrease the water pollution from the final (15).

Normally chlorine or chlorine dioxide based bleaching. In addition, it is an effluent free process. All dissolved lignin and other organics (as well as the inorganic chemicals) are recovered in the black liquor and returned to the chemical recovery system, rather than being discharged as effluent as they are in chlorine-based bleaching. Finally, oxygen is a fairly cheap bleaching chemical, although the capital costs are high for an efficient system. On the negative side, the process has the potential to degrade the pulp strength if it is not controlled properly. The final bleaching is always carried out in several stages to improve the efficiency of the chemicals used, and to decrease the strength loss of the pulp. There are quite a number of bleaching chemicals used commercially, and many more have been tried in the laboratory (14).

The chemicals used are:

- Chlorine
- Chlorine dioxide
- Sodium hypochlorite
- Oxygen
- Peroxide
- Ozone

From these chemicals, the first three contain chlorine atoms, whilst the last three use non chlorine oxidizing compounds. Elemental chlorine (Cl_2) was for many years the work horse of the bleaching process. It is efficient in bleaching the pulp and (if properly used) does not degrade the pulp strength. However, it produces a large amount of chlorinated organic compounds in the effluent, and strenuous efforts have therefore been made to decrease its usage. For the same reason, the use of sodium hypochlorite (which also tended to affect the pulp strength) is now virtually eliminated (5).

Modern bleach plants therefore use no elemental chlorine. They are what called ECF plants: elemental chlorine free bleach plants. Chlorine dioxide, which is used instead (in addition to non-chlorine compounds), is environmentally much more benign than Cl_2.However, while chlorine dioxide is good at preserving pulp strength, it is not as effective as elemental chlorine in delignification/bleaching. ECF plants therefore have to have a rather low incoming Kappa number, and this is normally achieved by using oxygen delignification ahead of the final bleaching (8).

Most ECF plants use a three step bleaching process of chlorine dioxide followed by a mixture of NaOH, O_2 and peroxide (the 'extraction' stage) and then finally chlorine dioxide again. Because of the efficiency of the oxygen delignification, the peroxide is no longer necessary and a sequence of chlorine dioxide then NaOH and O_2 followed by more chlorine dioxide is used.

The amount of chlorinated toxic compounds in the effluent from a correctly operated ECF plant is small (especially after secondary treatment) and the effects on the environment appear rather insignificant. However, especially in Europe, there is a perception that using "chlorine" in any form when bleaching is undesirable, and bleaching without using any form of chlorine compounds, so-called total chlorine free bleaching (TCF bleaching) has been developed. In TCF bleaching only oxygen, peroxide and ozone (in addition to caustic and certain chelating agents) are used. TCF bleached pulp can nowadays reach virtually the same brightness as ECF bleached pulp, but the strength is somewhat lower. Such plants require inevitably oxygen delignification and also, usually, cooking to a lower Kappa number. Chemical costs are also normally higher. TCF pulp is not made in New Zealand (1).

Figure2.3 bleaching of pulp(source: Gary A.smook, 1992)

2.8. Basic Pulp Properties

A) Pulp Consistency: is the term used to describe solid content of pulp during pulp processing. For pulp and paper maker this is the most important process parameters. All equipment's are designed to handle pulp at and up to certain consistency. Pulp consistency is roughly divided in to three ranges (12).

- Low Consistency: <5%
- Medium Consistency: 5 - 15%
- High Consistency: >15%

B) Moisture Content of Market Pulp is important from storage, transportation and handling point of view. Most of the market pulp are sold, stored, transported and used as air dry. The useable part of pulp is dry fiber only, so the tendency is to minimize the moisture content of pulp (7).

C) Viscosity of Pulp: Solution viscosity of a pulp gives an estimation of the average degree of polymerization of the cellulose fiber. So the viscosity indicates the relative degradation of cellulose fiber during pulping /bleaching process.

D) Bursting strength: Is a property of pulp or paper that measures its resistance to rupturing, defined as the hydrostatic pressure needed to burst a pulp sample when it is applied uniformly across its side. Bursting strength is a function of various processes performed in the pulp making process. The increased use of longer fibers and surface sizing increases a pulp's bursting strength. It is measured using a Burst tester (9)

E) Tensile strength of Pulp: Is the maximum strength of randomly oriented pulp fiber when formed in a sheet. This tensile strength gives an indication of the maximum possible strength of pulp beaten under ideal condition. This again an indication of what level of tensile strength can be achieved in real paper making environment (10).

Table2.5 Pulp properties

No.	Parameters	Standard (ASTM)
1	Burst	1.9kg/cm2
2	Breaking Length	4236 meters
3	Tear factor	108
4	Moisture Content	7-9%
5	Viscosity	250-330 CP
6	Consistency	>15

(Source: Wiley-VchVerlagGmbh and Co.KGaA,Weinheim,2006)

PROCESS FLOW DIAGRAM OF PULP PRODUCTION

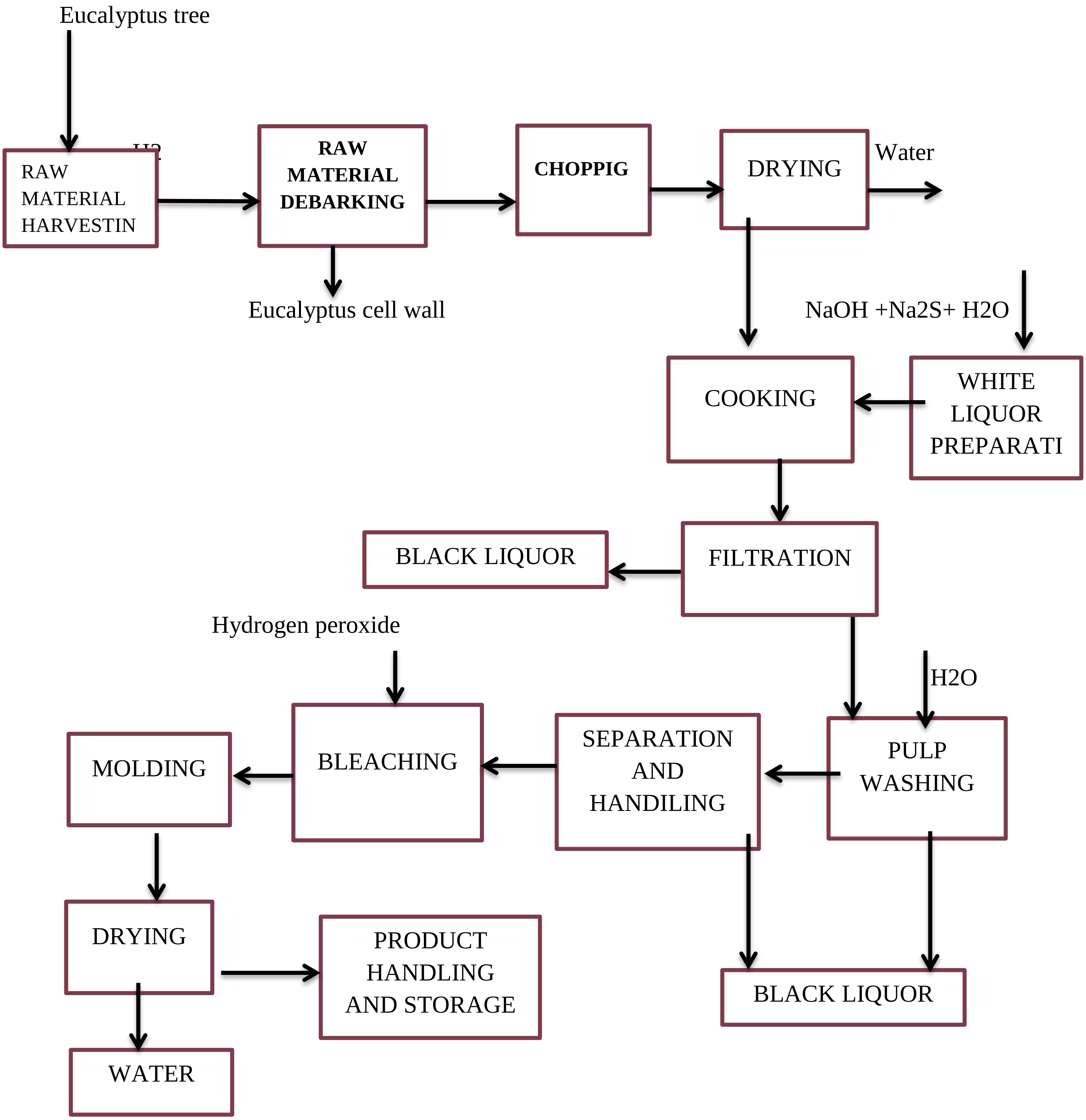

Figure2.4 flow diagram of pulp production

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PULP PRODUCTION PROCESS FLOW DIAGRAM

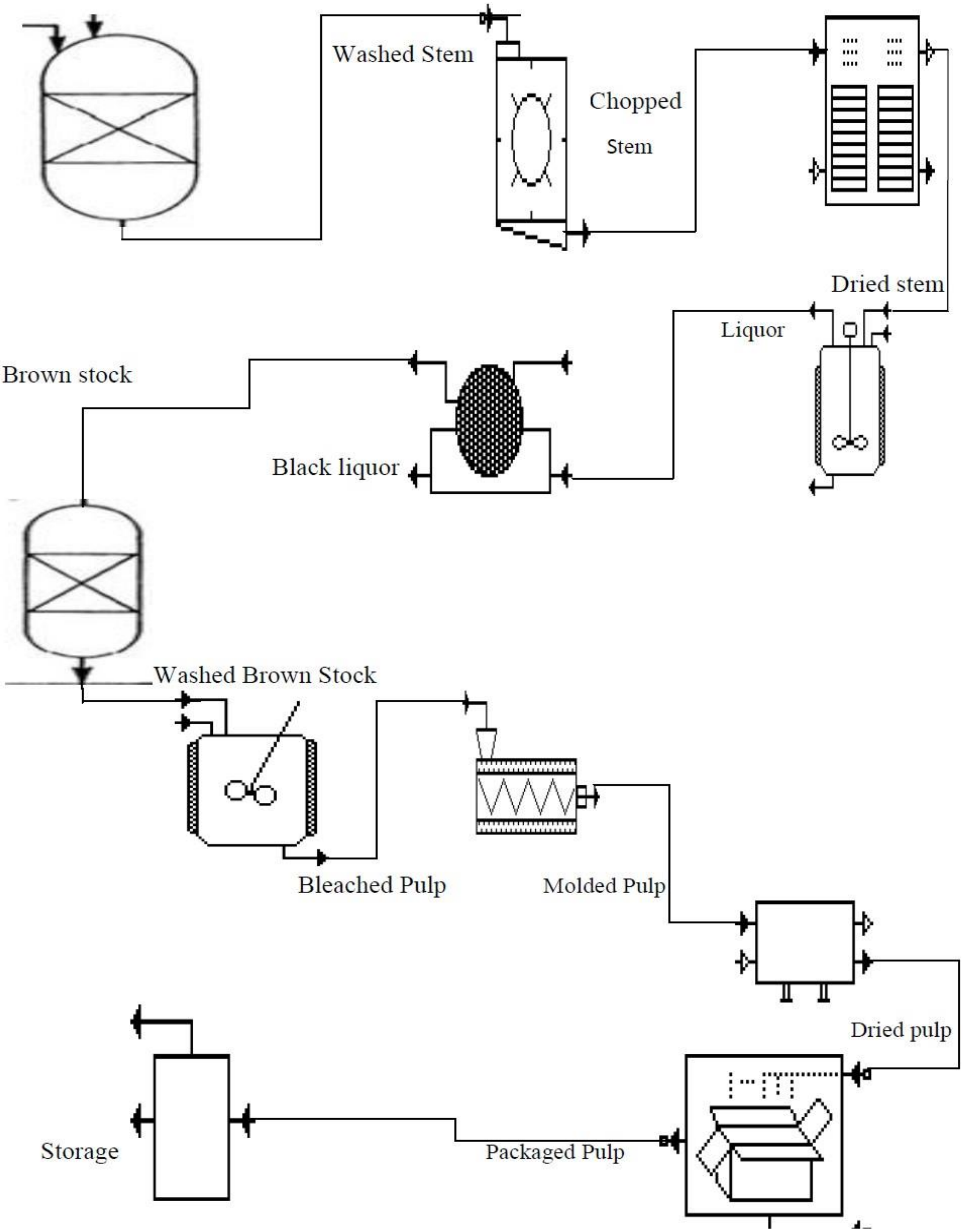


Figure2.5 process flow diagram of pulp production

2.9. Application of pulp

Pulp represents the major raw material basis for two main applications:

(A) For paper and board production, where the pulp fibers are mechanically modified to give a coherent sheet.

(B) For chemical conversion to products such as regenerated fibers and cellulose derivatives. The former is denoted as paper grade, the latter as dissolving grade pulp. Paper grade pulp is by far the most dominant field of pulp production. Sulfite pulp is characterized by rather week strength properties, and is typically used in products that require good sheet formation and moderate strength. Semi-chemical pulps with a typical residual lignin content of 10–15% represent the transition from mechanical to chemical pulps. Its primary use is for the production of corrugating medium as well as printing papers, greaseproof papers, and bond papers.

Kraft pulp is noted for its superior strength characteristics, and can be used in virtually all paper and paperboard grades in order to improve strength properties.

CHAPTER THRE

3. MATERIAL AND METHODS

3.1. Material used

- **Raw material**
  - Eucalyptus tree.

Chemicals

- ✓ NaOH
- ✓ Na_2S
- ✓ Water
- ✓ H_2O_2

Equipment's needed

- Balance
- Beaker
- Bleaching machine
- Burst tester
- Crusher
- Digester
- Disintegrator
- Drier
- Filter
- Flask
- Molding machine
- Heater
- Measuring cylinder
- miller
- Sheet machine
- Sheet press
- Tearing tester
- Tensile strength

3.2. Methodology

3.2.1. Material preparation

a. Raw material (eucalyptus tree) harvesting

Eucalyptus tree was harvested from Wolkite University manually without any price from society.

Figure 3.1 raw material harvesting

b. Debarking of raw material

The collected eucalyptus tree stem sample was debarked to remove the outer surface of stem (cell wall). This process was done manually by using axes and other harp material to make easy the debarking process.

c. Raw material Size reduction(Chipping)

The size of eucalyptus tree Axes, knife and miller.

Figure 3.2 Size reduced by using Axes(A) and knife(B)

Figure 3.3 Powder form of Eucalyptus tree

d. Raw material Dry by sunlight.

The milled raw material was dried by sunlight for one week to remove water in the raw materials.

3.2.2. Digestion or cooking process

A. White liquor preparation

I. Kraft pulping process

The white liquor prepared for Kraft pulping process was a mixture of NaOH, Na_2S and H_2O. For cooking liquor to be prepared chemicals must be taken in right proportions so that effective cooking would happen. Kraft pulping consists of following chemicals NaOH and Na_2S. Typically some 150 g of NaOH and 50 g of Na_2S are required per kilo gram of dry wood and white liquor to wood ratio of 4:1.

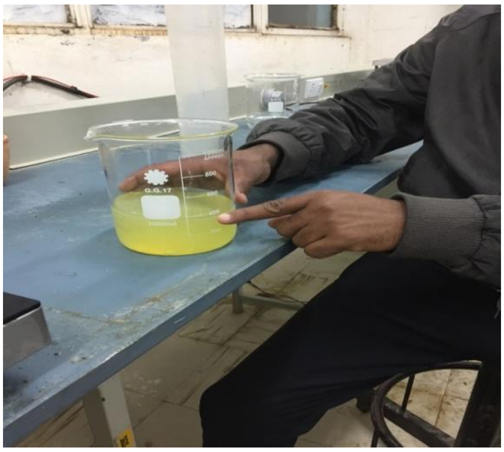


Figure 3.4 White liquor preparation

II. Soda process

Soda process required only NaOH for cooking liquor preparation; thus 150gm of NaOH is required for 1kg of dry wood sample.

B. Cooking (Digesting)

Raw material cooked with white liquor ratio of appropriate temperature at atmospheric pressure. Prepared white liquor which contains 20gm of NaOH, 8gm of Na_2S and 400ml of water took it into biker with 100grams of raw material (eucalyptus tree stem).

Figure 3.5 Cooking of raw material with white liquor

3.2.3. Filtration, pulp washing and screening

After digesting, brown stock and black liquor were formed. Brown stock contains pulp (cellulose and hemi-cellulose) and small amounts of lignin (reason for brown color) and the black liquor contains the dissolved lignin and cooked chemicals that are unconverted and can be recovered.

Therefore the mixture was filtered by using a sieve to obtain black liquor as waste that contains cooking chemicals which can be recovered. By one time filtration lignin traces doesn’t removed completely; so once the filtration is done it was again washed with water to remove lignin and chemicals associated with the brown stock to dissolve in it. The mixture was again filtered with filter (sieve) and the process was repeated. It was washed several times with1000ml of water to reduce the lignin content. We removed knots and clumped-together uncooked fibers from the pulp by our hands in order to form uniform size for the next process.

3.2.4. Pulp Bleaching by hydrogen peroxide chemical

As filtration, washing and screening was completed; the screened pulp was dissolved in hydrogen peroxide to remove the remaining brown color to obtain more white pulp.

Figure 3.6 Pulp bleaching by hydrogen peroxide

3.2.5. Drying

Drying was done to find the yield in both the processes. To find the yield entire water in the bleached pulp should be removed. To remove entire water content in the bleached pulp, it was dried at a temperature of 100ºC for one hour in hot air oven

Figure 3.7 Pulp drying

3.2.6. Pulp Packaging

Final product (pulp) was molded in designed shape, Packaged and then transport to storage.

3.3. Experiment

i. Experimental site

The laboratory based activities were carried out at Wolkite University; Chemical Engineering Department laboratory and Wolkite University chemistry department laboratory. The Kraft and soda pulping were conducted at Wolkite University; Chemical Engineering Department laboratory. In this project we had done three experiments the first experiment was production basic pulping methods i.e. Kraft and soda pulping. In the second experiment we done three trial based on Kraft pulping only.

ii. Experiment one Experiment one have two trial the first trial is by Kraft process and the second process is by soda process to compare the yield of two process.

Experimental frame work of the project

A) Kraft pulp frame work

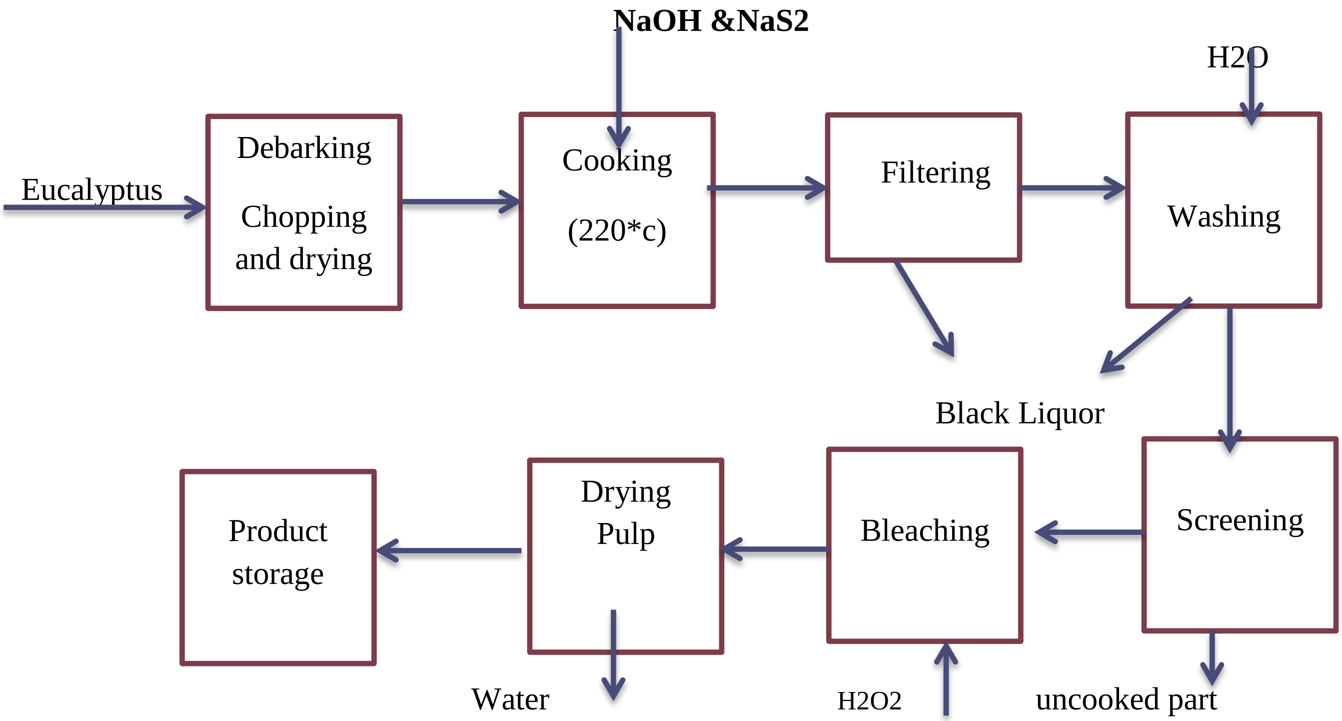


Figure 3.8 Kraft pulping flow Diagram

B) Soda pulping

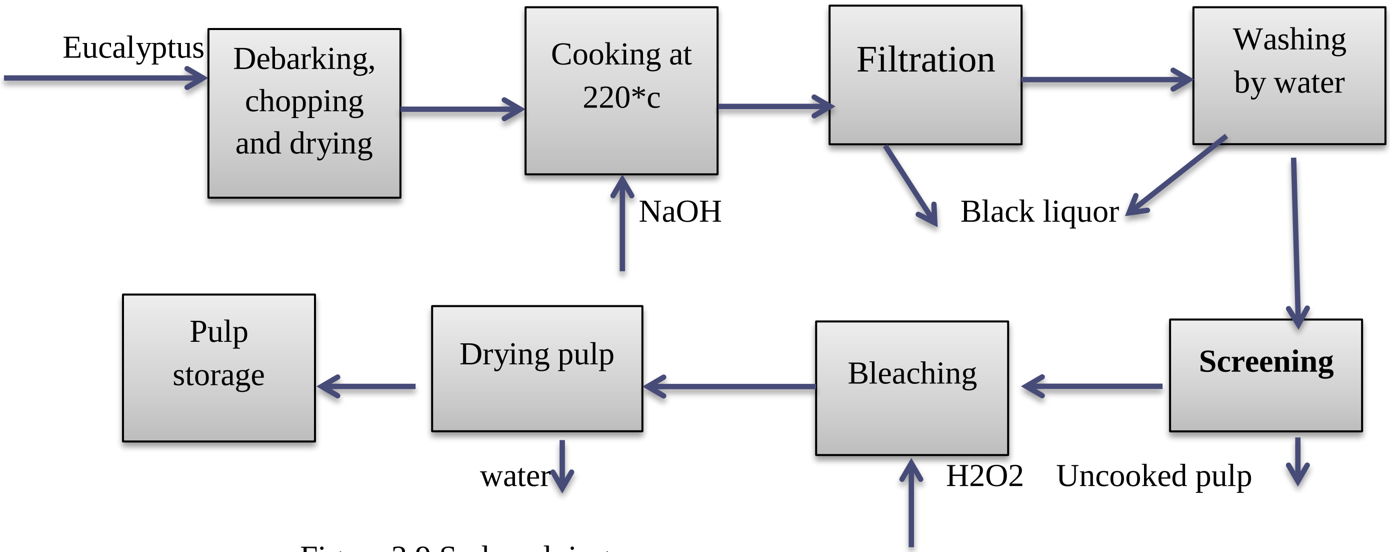


Figure 3.9 Soda pulping process

iii. Experiment Two.

The second experiment have three trial process by Kraft method compare with first experiment done by Kraft process (trial one compare with first experiment done by Kraft, trial two with first experiment and trial three was also compare with first experiment done by Kraft process. This experiment is done by changing the cooking temperature, changing chemical concentration and time of cooking. The first trial are done by changing cooking temperature from 220^{o}c to 170^{o}c and the next trial was done by changing cooking time from 5:30hr to 4:30hr and the 3rd trial was done by changing chemical concentration to get the optimum production. All raw material amounts are 100mg and used white liquor solution is 400ml.

CHAPTER FOUR

4. RESULTS AND DISCUSION

4.1 Experiment One: Kraft and soda pulping

A) Kraft pulping

Typically some 150 g of NaOH and 50 g of Na_2S are required per kilo gram of dry wood and white liquor to wood ratio of 4:1.

- Based on the above ratio we calculate the amount needed as follows

  If 150gm of NaOH=1000gm of dry wood

  x?gm of NaOH =100gm dry wood

  After calculate the value get 15gm of NaOH.
- According to the ratio of Na_2S to dry wood

  If 50gm of Na_2S=1000gm of dry wood

  x? Na_2S=100gm of dry wood

  After we calculate we get 5gm of Na_2S is needed
- According to the ratio of white liquor to wood (4:1) we prepare the amount of water needed as follow.

  Amount white liquor =4×100gm = 400gm
- Now amount water =amount water liquor –amount of the two chemicals exist

  =400gm-20gm =380gm

Consistency is a term used in the pulp and papermaking industry.

The consistency of a suspension is defined as $\boldsymbol{c = \frac{x}{y}}$

Where

- *C* is consistence
- *x* is the mass of pulp
- *y* is the mass of the rest of the suspension (usually mainly composed of water)

Consistence= $\frac{71}{156} * 100\% = 45.5$

Table 4.1 Summary result for Kraft process on each unit operation

Unit Operation	Amount(gm)
Before Debarking	168
Debarking	156
Chopping	156
Drying	100
Digesting(Cooking with white liquor solution)	428
Cooked mixture	235
Filtration	162
Washing	158
Screening	149
Bleaching	156
Drying	71

Moistur content $\text{MC}=\frac{X1-X2}{X1}*100\%$

$$\text{MC}=\frac{156-71}{156}*100\% = 54.48$$

Pulp Yield $y=\frac{x1}{x2}*100\%$

$$y=\frac{71}{100}*100\% = 71gm$$

Where

- ✓ x1 is product after drying
- ✓ X2 is product after bleaching

B) Soda pulping

Preparation of cooking liquor, In this process, 20% by weight solution of NaOH was required as cooking liquor. If we take 400ml as basis 20% by weight gives 80gm of NaOH. These 80grams of NaOH was dissolved in water and makeup to 400ml to give required concentration of cooking liquor.

Table 4.2 summary result for soda process on each unit operation

Unit Operation	Amount(gm)
Before debarking	168
Debarking	156
Chopping	156
Drying	100
Digesting(Cooking with white liquor solution)	480
Filtration	162
Washing	156
Screening	145
Bleaching	151
Drying	56

Consistency $C = \frac{x}{y} * 100;\quad C = \frac{56}{151} * 100\% = 37.08$

Moisture content $MC = \frac{X1-X2}{X1} * 100\%$

$$MC = \frac{151-56}{151} * 100\% = 62.9$$

Pulp Yield $y = \frac{x1}{x2} * 100\%;\qquad y = \frac{56}{100} * 100\% = 56$

- **Comparison result of Kraft process and soda process**

Table 4.3 Comparison of kraft and soda process

Parameter	Soda	Kraft
Consistency	37.08	45.5
Moisture content	62.9	54.48
Viscosity	-	-
Pulp yield	56	71

- Coming to the yield from the observations Kraft process gave more pulp for fixed amount of raw material when compared with Soda process. So, Kraft process was more advantageous.
- Kraft pulping chemical contain Na_2S and NaOH by small amount and take short time to break the lignin molecules in the dry wood fiber. Soda pulping contain NaOH chemical in high amount when compare with Kraft method and take long time to break the lignin molecules in the dry wood fiber. In this case the time used for cooking between soda pulping and Kraft pulping was different for Kraft process required only 5hr and 30min at 220^oc for breaking lignin molecules. But soda process required 8hr for digestion at 220^oc because of the chemical used in the Kraft process means Na_2S used to speed up of reaction in the process so soda pulping was required more heat energy and time.
- Kraft process consists of strong cooking liquor which can break the lignin more effectively. Whereas soda process consists of weak cooking liquor. Because of this reason, the uncooked raw material found in Soda process than Kraft process. The pulp obtained in Kraft process was less dark in color than pulp obtained in soda process when the product obtained after washing with water was compared in both processes; this was due to pulp obtained in Kraft process contain less lignin content in it due to strong basic nature of the solution which break the lignin effectively and Soda process involves weak basic cooking liquor that acts weak in breaking lignin bond. The pulp obtained after bleaching was observed and found that Kraft pulp was whiter in color compared to soda process, as bleaching agent required breaking the traces of lignin was more in soda process than Kraft process.
- Pulp obtained after washing is added with bleaching agent. The amount of bleaching agent required is more in Soda process when compared to Kraft process. So, the pulp obtained in Kraft process can be used for high grade paper production and pulp obtained by Soda process can be used for low grade paper production, but the discussion here was about the packing paper, so, the pulp must be entirely lignin free, because it acts as an impurity and may vary the conditions of the packed material. These conclude that Kraft process is better than soda process.

4.2. Experiment two:

Depend on parameter emperature, Chemical Concentrations and Time effect

Trial One: cooking temperature 170^{o}c for 5:30hr for equal sample and equal cooking liquor with experiment one by kraft process.

Table 4.4 pulp cooked at 170^{o}c for 5:30hr

Main unit operation	Amount of product in gm.
Sample	100
Digesting (cooking solution)	428
Cooked mixture	283
Filtration	159
Washing	160.5
Screening	133
Bleaching	147
Drying	63.7

- From table 4.4 when compare the result with first experiment (table 4.1) result: the raw material was more digested with temperature at 220^{o}c than 170^{o}c, the amount of lignin was more remove at temperature 220^{o}c, the product on first experiment greater than trial one result by 7.3% and more color change observed. Therefore the temperature used for cooking at 220c appropriate for yield and quality of pulp.

Trial two: chemical concentration difference with first experiment by kraft process for the same sample and the same cooking. 150gm of NaOH and 50gm of Na_2S for 500gm of dry wood respectively

Table 4.5 pulp cooked by difference of chemical concentration by kraft

Unit operation	Amount of product in gm.
Sample	100
Digesting(cooking solution)	450
Cooked mixture	233
Filtration	164
Washing	140
Screening	135
Bleaching	162
Drying	73.4

- By comparing the result of table 4.5 and table4.1 of Kraft process observe the effects of chemicals concentration applied to the raw materials; and observe that the raw materials which was digested by more chemical (table 4.5 result) was more black liquor removed; than the less chemical applied (table4.1 result). Additionally observed that the more chemicals applied pulp was more brown color than the less applied one; the product gained by trial two was greater than experiment one result by only 2.4%. Using highly concentrated cooking liquor was good for removal of lignin from raw material but it is much cost to use it at industrial level.

Trial three: cooking time difference (trial three 4:30hr) with the first experiment done by kraft process (5:30hr) for all other parameters are the same

Table 4.6 pulp cooked for 4:30hr by 220^{o}c

Unit operation	Amount of product in gm.
Sample	100
Digesting(cooking solution)	428
Cooked mixture	230
Filtration	165
Washing	163.5
Screening	119
Bleaching	155
Drying	59.6

- By compering this result with the result of first experiment the first experiment result greater by 11.4% from this and also much amount of raw material was not perfectly cooked so that on screening process much uncooked wood stem was removed. The product obtained from this trial was brown than the first experiment.

CHAPTER FIVE

5. ENGINEERING ANALYSIS

Material quantities, as they pass through processing operations, can be described by material balances. Such balances are statements on the conservation of mass. Similarly, energy quantities can be described by energy balances, which are statements on the conservation of energy. Material and energy balances are very important in an industry. Material balances are fundamental to the control of processing, particularly in the control of yields of the products. When any changes occur in the process the material balances need to be determined again. The increasing cost of energy has caused the industries to examine means of reducing energy consumption in processing. Energy balances are used in the examination of the various stages of a process, over the whole process and even extending over the total production system from the raw material to the finished product. The energy balance determinations are also made to determine the energy requirements of the process, the heating, cooling and power required.

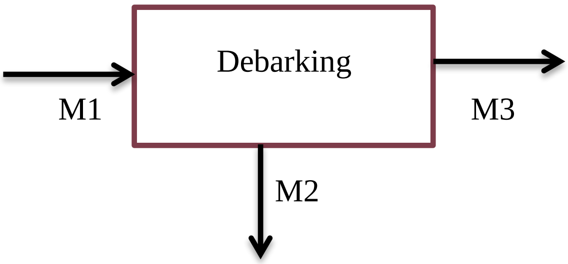
5.1. Material balances

Basic Assumptions:

- Steady state for all calculations i.e. Input=output
- Production capacity of the plant is = 15,000kg/day
- Plant working time is=320day/year

- Lab scale material balance on basic unit operation

1. Debarking



Where

$M_{1=}$ mass of stem wood

M_2=cell wall (removed outer surface of stem)

M_3=debarked wood

- $M_1=M_2+M_3$

$168gm=m_2+156gm$ $M2=12g$

II. Industrial scale

at lab scale we get 71gm of pulp product from 100gm of raw material so that from our assumption we can calculate for Industrial scale.

71gm =168gm

15,000kg = X

$$x = \frac{0.168*15,000}{0.071} = \text{ 35,492.957kg/day of Raw Material}$$

Where X = is total amount of raw material (Eucalyptus tree) used per day

From lab scale material balance the total cell wall is 7gm by mass

- ✓ From the above two information we can calculate total amount of cell wall per day at industrial scale.

  0.168kg of raw material = 0.012kg raw material

  35492.9577kg of raw material = Y

$$Y = \frac{21{,}126.76kg/day * 0.012kg}{0.168kg} = 2535.2kg/day\ cell\ wall$$

2. Chopping

I. Lab scale material balance

Assumption- There is a little loss in the Chopper, but we neglect it

Input=out put

M1=M2

156gm=M2

II. Industrial scale

M1 = M2

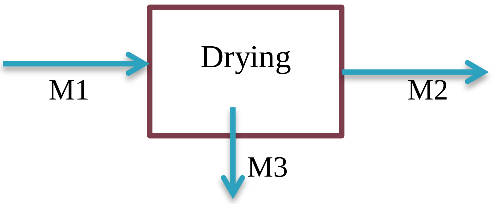
32957.76 = 32957.76

By neglecting some amount of raw material that lost by chopping process

3. Drying

I. Lab scale material balance

Eucalyptus tree chopped was sent to drier.



Mass input =mass out put

M1 =M2+M3

Where; M1= 156gm mass of chopped eucalyptus

M2= mass water removed

M3= 100gm mass of raw material after drying

M2 =M1-M3

= 156gm – 100gm

= 56gm of water is removed

II. Industrial Scale

From above lab scale information

156gm = 56gm

32957.76kg/day = X **kg/day**

$$X = \frac{56 * 32957.76}{156} = 11{,}830.98 kg/da$$

4. Digesting

I. Lab scale material balance

100gm Eucalyptus tree stem was sent into a digester with 428mlof cooking liquor for 5:30hr and later brown stock and black liquor is formed. During this cooking process a lot of water is evaporated.

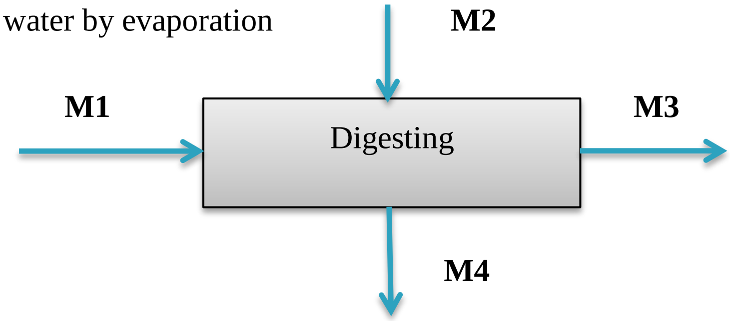
M1+ M2 = M3+M4

Where M1 =100gm mass chopped and dried raw material

M2 =428ml of cooking white liquor

M3 =162gm mixed cooked stock

M4= mass of removed water by evaporation



M1+M2 = M3+ M4

M3 = M1+ M2 – M3

= (100+428) – 235

= 293ml of water is evaporated during Cooking.

II. Industrial scale

From above lab scale material balance we can calculate the amount of water evaporated during pulp cooking process.

- **Amount of NaOH** required for white liquor solution preparation

100gm = 20gm of NaOHgm

21126.76KG = X KG

From this relation

$$X = \frac{21126.76kg * 20gm}{100gm} = \frac{4225kg}{day}\ of\ NaOH\ is\ required$$

- **Amount of Na2S required**

100gm = 8gm of Na2S

21126.76kg = Xkg of Na2S?

$$Na2S = \frac{(21126.76kg * 8gm)}{100gm} = \frac{1690.14kg}{day}\ required$$

- **Amount of water require** for preparation of white liquor

100gm = 400ml water is require

21126.76kg = Xml of water is required

$$water\ required\ = \frac{21126.76kg * 0.4L}{0.1kg} = 84507.04L/day$$

From the above information we can calculate total amount of water removed by evaporation during cooking process of pulp.

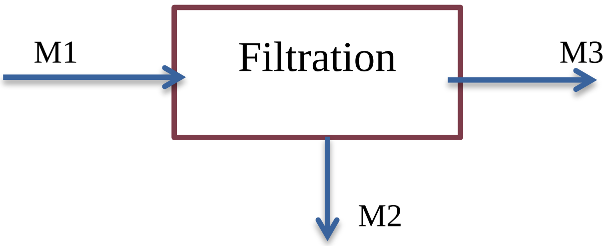
M1 + M2 = M3 +M4

21126.76KG +90,422.54L = 34,436.6KG +M4

M4 = 77,112.7L of water is removed during cooking of pulp

4. Filtration

I. Lab scale Balance



M1 = M2 + M3

Where M1 is mass of digestion

M2 is amount of black liquor removed

M3 is amount of filtered pulp

$$M1 = M2 + M3$$

$$235 = M2 + 162$$

M2 = 73 ml of black liquor cooking chemical and water is removed by filtration

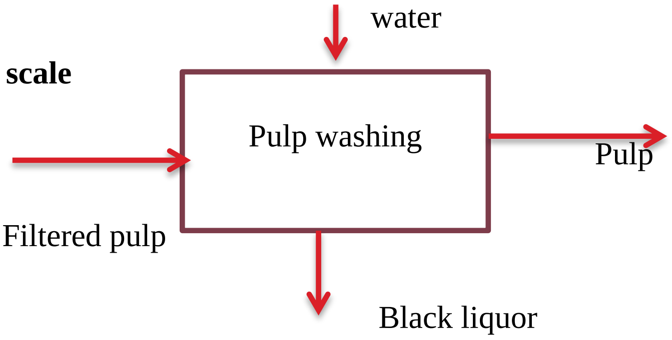
II. Industrial Scale

From this relation $X = \frac{73\text{ml} * 21126.76\text{kg}}{0.1\text{kg}} = \frac{1542253.48\text{ml}}{\text{day}}$

X= 1542.25L or 1.5m3 mixture of black liquor, water and chemical is recovered per day

1. Washing

I, Lab. scale



$$M1 + M2 = M3 + M4$$

Where M1= filtered pulp

M2 = water added

M3 = washed pulp

M4 = amount of black liquor and water removed

$$162gm + 1000gm = 158gm + M4$$

$$M4 = 1162gm - 158gm$$

= 1004gm of water and black liquor mixture is removed per each washing times

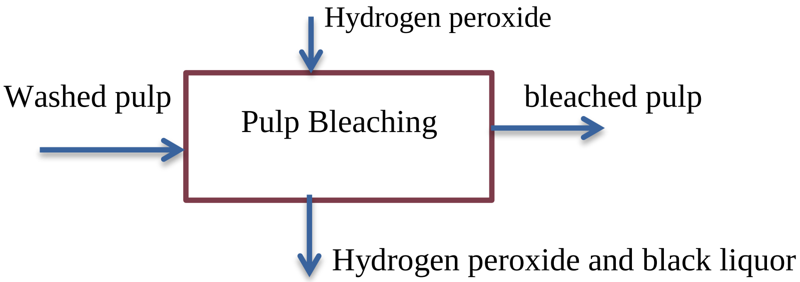
II, Industrial scale

Amount of water used during washing time per day

21126.76 kg* 1004gm/158gm

= 134248.24kg or 134248.24L of water used per day

2. **Bleaching**



M1 + M2 = M3 + M4

Where

M1 is washed pulp

M2 is hydrogen peroxide

M3 is bleached pulp

M4 is removed

M4 = M1+M2 – M3

M4 = 162 gm+ 200gm – 158gm

M4 = 204gm

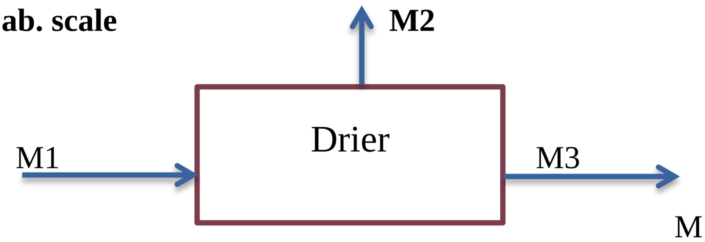
II, **Industrial scale**

= 21126.76kg * 204 gm/158gm

= 27,277.6kg

Pulp drying

I, Lab. scale



M1 = M2 + M3

M2 = M1 – M3

M2 = 156 – 71

M2 = 85gm of water evaporated

Where M1 = mass of bleached pulp

M2 = mass of water evaporate

M3 = mass of dried pulp

II, Scale up to Industry

Mass of water evaporated during pulp drying is calculated as

$$\text{mass of water evaporated} = \frac{85\text{gm} * 15000\text{kg}}{71\text{gm}} = 17957.7\text{kg of water is removed perday}$$

5.2. Energy Balance

Steady state process

Energy in+ $\cancel{\text{energy generation}}$ = energy out + $\cancel{\text{energy consumption}}$ + $\cancel{\text{energy accumulation}}$

Energy in = energy out

Energy Balance on Drier

Q= mcp (Tin- Tout)

Where

Q = heat needed

m = mass of pulp enter to the dryer = 156gm

p = specific heat capacity of liquor = 3.67kj/kg

Tin =temperature of pulp before drying = 28^{o}c

Tout = temperature of pulp out of dryer =100^{o}c

Drying time 1hr

1kg=1000gm

X = 71gm

Mass flow rate=0.071kg/60min=0.00118kg/min

Q=0.00118kg/min x3.67kJ/kg^{O}C x (100^{o}**C** -28^{o}**C**)

Q=0.3067kJ/min of energy required per minute

CHAPTER SIX

6. MATERIAL SIZING

Table 6.1 density of material

Substance	Density Sizing (kg/m^3)
Eucalyptus tree	570
NaOH	2130
Na_2S	1856
H_2O_2	1450
H_2O	1000

6.1.1. Sizing of chopper Equipment

Mass of eucalyptus stem=21126.76kg/day

- ✓ If the company have three batch

$$mass\ per\ batch = \frac{\frac{32,957.75kg}{day}}{4} = \frac{8,239.43kg}{batch}$$

$$density = \frac{mass}{volume}$$

- ✓ Volume of eucalyptus stem $\text{volume} = \frac{\text{mass}}{\text{density}}$

$$\text{volume} = \frac{8,239.43\text{kg}}{570kg/m3} = 14.45m3/batch$$

- ✓ Safety factor 10% = 0.1*14.45m3/batch + 14.45m3

= 15.895m3/batch

6.1.2. Sizing for dried

$$drier\ volume = \frac{mass\ of\ eucalyptus\ enter\ to\ drier}{desity\ of\ eucalyptus\ tree}$$

$$volume = \frac{32957.76kg/day}{4batch * 570kg/m3} = 14.45m3$$

With safety 10% volume of drier = 15.89m3

6.1.3. Sizing of Digester Equipment

Volume storage of digesting=volume of NaOH +V of Na_2S + Volume of dry chopped +Volume of water. A. **Volume chopped dry wood** $volume\ of\ dry\ wood = \frac{mass\ of\ wood}{desity\ of\ wood}$

$$volume\ of\ dry\ wood = \frac{21126.76kg}{\frac{570kg}{m3} * 4\ batch} = 9.266m3$$

A. Volume of water $volume\ of\ water = \frac{mass\ of\ water\ usd}{desityof\ water}$

$$volume\ of\ water = \frac{84507.04kg\ of\ water}{\frac{1000kg}{m3}} = 84.5m3$$

B. Volume of NaOH storage $volume\ of\ NaOH = \frac{mass\ of\ NaOH}{Desity\ ofNaOH}$

$$volume\ of\ NaOH = \frac{4225KG/day}{2130kg/m3} = 1.98m3$$

C. Volume of Na_2S Volume of Na_2S = mass of Na_2S / Density of Na_2S

$$volume\ of\ Na2S = \frac{1690.4kg/day}{1856kg/m3} = 0.91m3$$

$$\text{volume of digester} = \text{volume of dry wood} + \text{volume of water} + \text{volume of NaOH} + \text{Volume of Na2}S$$

= 84.5m3 + 9.266m3 +1.98m3 + 0.91m3

=96.65m3

With safety factor volume of Digester = 106.31m3

Volume of digester per batch = 106.31/4batch 26.578m3 per batch with safety factors.

CHAPTER SEVEN

7. ECONOMIC ANALYSIS

7.1. Purchasing equipment cost

-The purchasing costs of equipment is estimated using website

(http://www.mhhe.com/engcs/chemical/petersdahtml)

www. Alibaba equipment cost .com

Table 7.1 Purchasing Equipment price

Eq. No.	Eq. Name	Capacity	Quaty	Material	Unit cost($)	Amount($)
PPW-	Vacuum Drum washer	$26m^3$	2	Carbon steel	39,432	78,864
PPD-	Dryer	$15m^3$	4	304 Stainless steel	42,505	170,070
PPDG-	Digester	$27\ m^3$	4	304 Stainless steel	28,659	114,636
PPVD-	Vacuum filter	$11m^2$	2	304 Stainless steel	22,260	44,520
PPV-	Bleaching	$7\ m^3$	2	304 Stainless steel	20,988	41,976
PPM-	Molding	$10\ m^3$	2	304 Stainless steel	38,160	76,320
	Screener(sieve)	$3m^3$	2	304Stainless steel	20,780	41,560
PPP-101	Packaging		2	304 Stainless steel	25,440	50,880
	White liquor storage	$3m^3$	2	Carbon steel	20,000	40,000
PPS-101	Storage	$10m^2$	2	Building with	20,980	41,960
	Debarking	68kg/hr	2	Carbon steel	6000	12,000
	Chopper	881kg/hr	2	Carbon steel	30,528	61,056
Total						**773,842**

7.2. Estimation of capital investment cost

7.2.1. Fixed capital investment (FCI) estimation

A) Direct Cost (DC)

Table 7.2 direct cost Estimation

Name of direct	Percent of PEC(%PEC)	Percent token	Amount
Installation including	25-55%	26%	$201,198.92
Instrumentation and control	6-30%	18%	$139291.53
Piping	10-80%	15%	$116076.3
Electricity	40-70%	25%	$193460.5
Building, process and Auxiliary	40-100%	50%	$386921
Service facilities	40-100%	40%	$309536.8
Land	4-8%	4%	$30953.68
Total cost			$1,377,438.73

B) In direct cost(IC)

Table 7.3 In direct cost estimation

Indirect cost	By Percent	Percent we took	Amount
Engineering and supervision	5-30% of DC	10%	$ 137,743.87
Construction expense & Contractor fee	6-30% of DC	8%	$ 110,195.098
Contingency	10%of FCI	10%	$ 137,743.87
Total cost			$ 385,682.746

7.2.2 Fixed Capital Investment

(FCI) = DC+IC=$ 1,377,743.87 + 385,682.746 + (0.1*FCI)

FCI = $ 1,939,769.26

Working Capital investment (WCI) = 15% of TCI ……………………………………… (1)

Total Capital Investment (TCI) = FCI + WCI…………..…………………………… (2)

From the above two equations:

WCI **=** $290,965.4

Total capital investment (TCI) = (FCI) + (WCI)

FCI = 1939769.26

WCI = 290,965.4

= $ 2,230,734.65

7.2.3. Total production cost (TPC) estimation

- Fixed Charges (FC):

- Depreciation = 10% of equipment cost + (2-3%) of building Cost

=0.1*$773842 + $ 0.02 *386921

= 77,384.2 + 7,738.42

= $ 85,122.62

- Local taxes (1-4%FCI) = 2.5% of FCI = 0.025 *$1,939,769.26

=$ 48,494.23

- Insurance (0.4-1%FCI) = 0.6% of FCI = $ 1,939,769.26 * 0.006

= 11,638.61

- **Total Fixed Charge (TFC) =** summation of the above fixed charge

Depreciation cost + local taxes cost + insurance cost

= $85,122.62+ $48,494.23 + $11,638.61

= $145,255.46

Total fixed charges = 15% of total product cost (TPC)

$$\text{TPC}=\frac{\text{Total fixed charges}}{15\%}=\frac{145{,}255.46}{0.15}=196{,}369.73$$

TPC = 196,369.73

7.2.4. Direct Production cost (DPC):

1. Raw material and inputs: (10-50% of TPC), take 30% of TPC
   = 196,369.73* 0.3
   = $58,910.9
2. Operating labor (OL): (10-20% of TPC), take 15% of TPC
   = 196,369.73*0.15
   = $29,455.35
3. Direct supervisor and clerical labor: (10-25% of OL),take 18% of operating labor
   = 0.18*29,455.35
   = $ 5,301.9
4. Utilities: (10-20% of TPC), take 15% of TPC
   = 15%* 196,369.73
   = $29,455.46
5. Maintenance and repair(M& R):(2-10% of FCI), take 6% of FCI
   = 6% * 1,939,769.26
   = $116,386.15
6. Operating Supplies:(0.5-1% of FCI), take 1% of FCI
   = 0.6% * 196,369.26
   = $1,178.2
7. Laboratory Charges: (10-20% of OL) we take 15% of OL
   = 15% * 29,455.35
   = $4,418.3
8. Patent and Royalties:(0-6% of TPC) 3% of TPC
   = 3% * 196369.73 = $5,891.09

Direct product cost (DPC) = the summation of the above production cost

DPC = \$250,997.35

Table 7.4 Direct Production cost (DPC)

Direct product Cost	By Percent	Percent taken	Amount per month
Raw material	10-50% of TPC	30%	\$58,910.9
Operating labor	10-20% of TPC	15%	\$29,455.35
Direct supervisor and clerical labor	10-25% of OL	18%	\$5301.9
Utilities:	10-20% of TPC	15%	\$29,455.46
Maintenance and Repair	2-10% of FCI	6%	\$116,386.15
Operating Supplies	10-20% of M & R	15%	\$1,178.2
Laboratory Charges	Laboratory Charges	15%	\$4,418.3
Patent and Royalties	Patent and Royalties	3%	\$5,891.09
Total cost			\$250,997.35

Plant overhead cost (POC): (5-15% of TPC), take 8% of TPC = \$15,709.57

Manufacturing cost = FC + DPC + POC

= \$411962.388

General expense

General expense= Administrative costs + distribution and selling costs + research and development costs + Financing (interest).

- Administrative costs (2-6% of TPC), take 4% TPC

=196,369.73 * 0.04 = 7854.789

- Distribution and selling costs (2-20% of TPC), take 11% of TPC

= 196369.73 * 0.11 = 21,600.6

- Research and Development costs = 5%TPC

=196369.73 * 0.05 = 9818.5

- Financing (interest) = 5% total capital investment

= 0.05*$2,230,734.65 = $111,536.73

Therefore, general expense is the summation above

= 7854.78 + 21600.6 + 9818.5 + 111536.73 = $150,810

Working day= 320 day per year

From material balance we expected to produce 15,000kg/day

Our product per year is = 15,000kg/day* 320day/year = 4,800,000kg/year

Pulp per Package =0 .1 tons

Number of Package per year = 4800/0.1 =48,000 Package

Price of pulp = $50/package

Total sale of Pulp per year = $2,400,000

Profitability analysis

Gross profit = product sales revenue–total product cost

Gross profit = Sj – Coj

= $2,400,000per year -$223074.6 5= 2,176,925.35

Assume: salvage value = 0 and plant service life = 15 year.

Therefore depreciation cost = (fixed cost - salvage value) /service life.

Depreciation = (FCI-salve value)/ service time

= 1,939,769.26 – 0 /1 = 129,317.9 per year

Gross profit including depreciation

Gp = Sj - dj = $2176925.35/year - $1939769.26 /year =$237156.09/year

Net profit = gross profit with depreciation (1-Ø)

= 237156.09 / 0.7 = 338,794.4

where, Ø= income tax of rate Ethiopia=30%

Minimum acceptable rate of return (pulp)

Minimum acceptable rate of return for new capacity with established corporate with low levels of risk=12%

Rate of Return an Initial Investment (ROI)

$$\boldsymbol{ROI} = \frac{\text{net profit}}{\text{total capital investiment}} = \frac{338{,}794.4}{2230734.65} * 100\% = 15\%$$

Payback period

$$PBP = \frac{FCI - Salvage}{netprofit + depriciatio}$$

$$PBP = \frac{1939769.26 - 0}{338794.4 + 129317.9} = 4\ .1 year$$

CHAPTER EIGHT

8. SITE SELECTION AND ENVIRONMENTAL CONCERNS OF PULPING

8.1. Site location

There are several aspects to be considered regarding the sitting and operation of pulp plant. First, a suitable site must be chosen and second the plant layout must be planned after the site characteristic are assessed, finally an environmental impact analysis needs to be performed to ascertain the expected effect of the plant and the chemicals on the surrounding areas. There are a number of considerations concerning the choice of site location for a pulp plant within Ethiopia.

The consideration relevant to this Study includes:

- Raw materials availability (eucalyptus tree)
- Markets
- Energy availability
- Climate
- Transportation facilities
- Water supply
- Availability of labor force
- Good infrastructure like road , water, electricity, health center and other

Depending on this factor Wolkite is most preferable, it also good fundamental infrastructure facilities, raw materials can be collected from different surrounding areas for the plant.

8.2. Environmental Impacts

The major negative environmental impacts of the project include the black liquor from Digester process, unless it is treated (recover chemicals for reuse in the pulping process). Also during the manufacturing activities of the pulp there is also a generation of

Waste water: This will have an adverse effect on the environment.

Air pollution:- air emissions in pulp production consist of process gases which vary by type of pulping process and which may include sulfur compounds (with associated odor issues), particulate matter, volatile organic compounds, chlorine, carbon dioxide, and methane.

Solid waste uncooked raw material, cell wall of tree and other spent raw material must be properly handled in order to protect the working environment and the environment of factory from damage

Noise: the high noise of the factory disturb the society if it located in the town so that it must be located somewhat far from the place where densely populated area.

CHAPTER NINE

9. CONCLUSION AND RECOMENDETION

9.1. Conclusion

This project would conclude that Pulp production has become a very important aspect of individual and country economies. Presently, most of the pulp being used in our country today was imported. The Pulp industry which uses the raw materials of eucalyptus trees has been established and fabricated to enhance the production problem of pulp locally, thereby reducing losses to the Ethiopian economy due to foreign exchange. This was done because of the Eucalyptus tree fiber is a potential raw material for making pulp and it's easily availability in Ethiopia. Production of pulp from Eucalyptus tree material is economically feasible and create good investment opportunity for investors went to participate on pulp and paper production industry.

By comparing the Kraft process and soda process, depending on yield, chemical used and energy conception Kraft process gave more pulp for fixed amount of raw material when compared with Soda process. So, Kraft process is more advantageous.

By comparing the four trial done by kraft process by changing cooking time, temperature and chemical concentration; to get the optimum pulp production condition depending on product, energy and economic, we conclude that production of pulp by kraft process at 220*c for 5:30hr was good than the reset.

9.2 Recommendation

- Insufficient laboratory equipment and chemical make great influence on the product quality, characterization of raw material and product characterization. By using proper chemical and equipment with proper chemical to raw material ratio at proper temperature and cooking time high quality quantity of pulp may produce.
- The characterization of raw material and product was not done due to luck of laboratory equipment, so that characterization of raw material and product was help to decide the feasibility of pulp from eucalyptus tree
- The black liquor from the digestion, waste water, bleaching chemical and some solid waste causes environmental problems so by recovering Chemicals like NaOH and Na_2S, treating waste water before released to river or environment and preparing solid waste disposal place can decrease the environmental impacts.
- Detailed economic feasibility studies in the production process were recommended.

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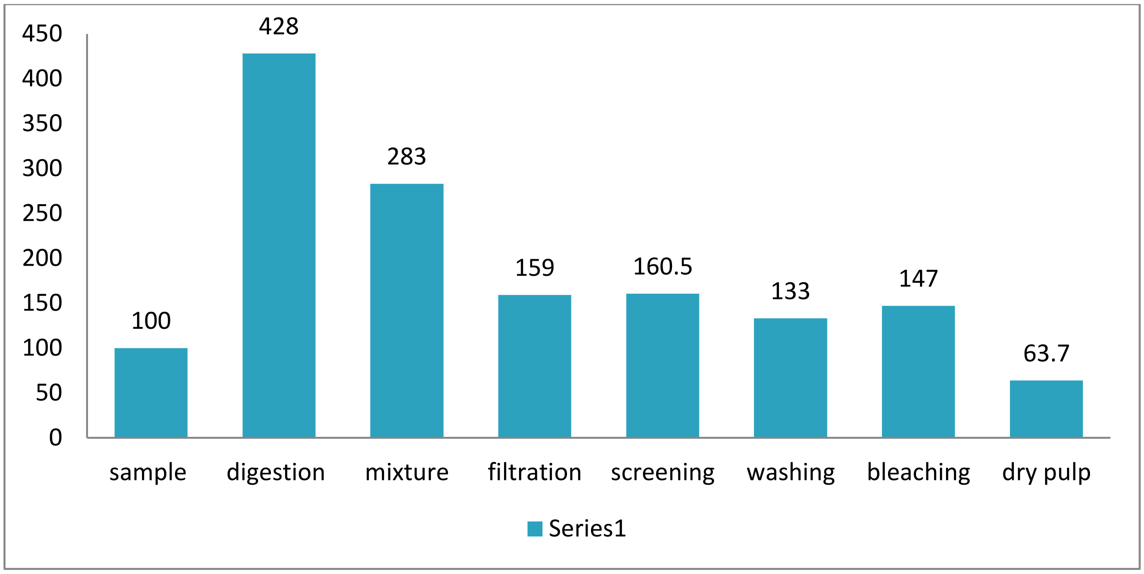
APPENDIX



Figr. 1. pulp cooked at 220*C for 4:30hr

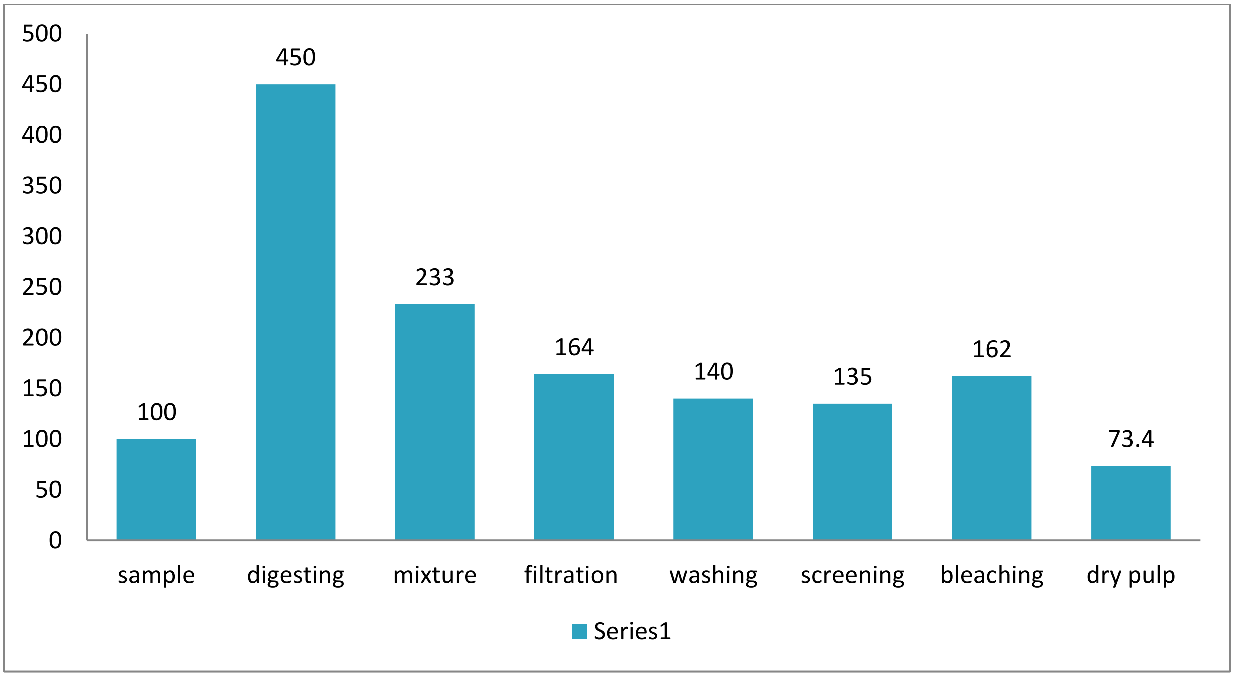


Figure 2. pulp at 170*C for 5:30hr

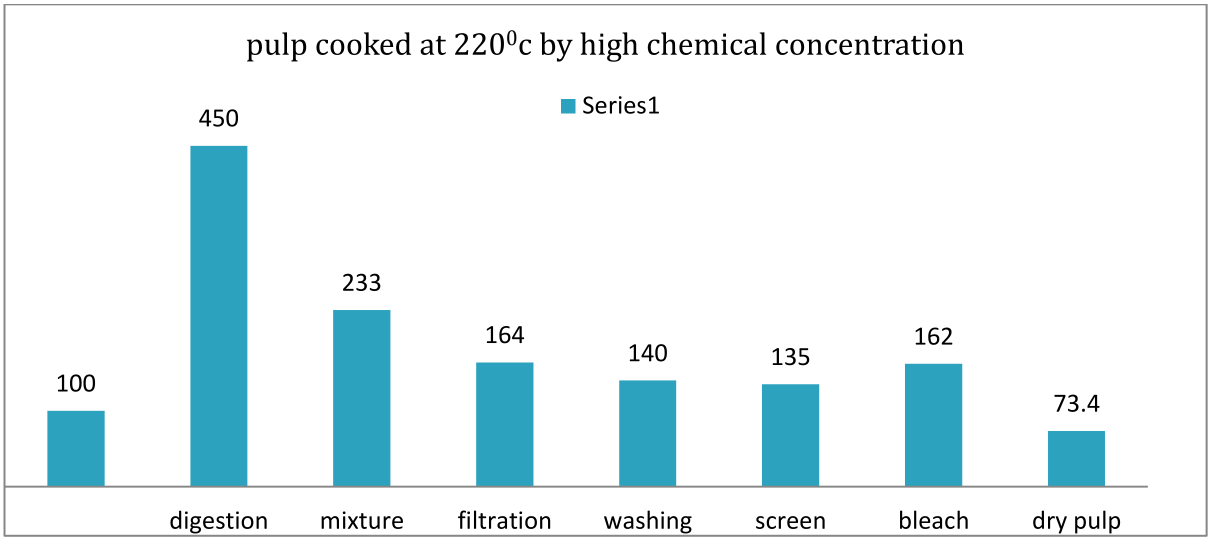


Figure 3 pulp cooked by high concentration of chemichal for 5:30hr

Figure 4 pulp cooking

Figure 5 pulp bleaching process