

# Production of Pulp from Banana Pseudo stem for Grease Proof Paper

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## ABSTRACT

Now a day, the dependency of mankind on polythene has grown to larger extent because of its wide applications in storing food without allowing the moisture inside the packing and also as carry bags. But polythene is a non-biodegradable material which when buried in the soil doesn't decompose. Because of this reason the soil loses its fertility due to the toxic chemicals it releases by the action of temperature and also killing the micro organisms that are essential in the soil.

In view of this, several attempts were made in recent years to develop paper that can show the oil proof as that of polythene. This project involves not the production of paper but the basic raw material for paper production that is pulp from banana plant (abundantly available on earth). Later this pulp can be blended with pulp obtained from bamboo which is less abundant, to obtain oil proof paper. The reason behind the selection of banana as raw material is, in banana plantations, after the fruits are harvested, the trunks or stems will be wasted. Billion tons of stem and leaves are thrown away annually.

In this project we are producing pulp from banana waste stem using Kraft's process and Soda process, also analyse the both process based on their yield, energy consumption and propose the best process.

**KEYWORDS:** Paper, Pulp, Banana Pseudo stem, Pentosan, Lignin, Krafts process, Bleaching

## INTRODUCTION

Paper manufacturing marks the beginning of the knowledge revolution. In ancient India knowledge spread verbally through the word of mouth from the teacher to the disciple, hence it was called Shrutu. But with the discovery of scripts, written records gradually replaced the verbal transmission of thought.

From then on paper is used as the major source of communication in the form of writing letters, keeping records of valuable information like books, entertaining people in the form of novels and spreading information about the daily happenings in the form of news papers, which is the major revolution in communication that ever happened in the history of mankind.

With various technologies available for production of paper, made itself use full in lots of applications. It not only has role in communication but also to large extent in packing materials (low grade paper), which is reason for selection of this project.

Now a day, the dependency of mankind on polythene has grown to larger extent because of its wide applications in storing food without allowing the moisture inside the packing and also as carry bags. But polythene is a non-biodegradable material which when buried in the soil doesn't decompose. Because of this reason the soil loses its fertility due to the toxic chemicals it releases by the action of temperature and also killing the micro organisms that are essential in the soil. So, this polythene material can be recycled from wastes rather than forcing it to decompose which is of no use. But at the same time recycling also has become costly with the increase in polythene use.

In view of this, several attempts were made in recent years to develop paper that can show the oil proof as that of polythene. This project involves not the production of paper but the basic raw material for paper production that is pulp from banana plant (abundantly available on earth). Later this pulp can be blended with pulp obtained from bamboo which is less abundant, to obtain oil proof paper.

## OBJECTIVES

1. To produce pulp from Banana plant pseudo stem by using both Kraft process and soda process.
2. To analyze the results obtained in the processes and to propose the better process based on yield and consumption of raw material and energy.

## LITERATURE REVIEW

T Goswami, Dipul Kalita\* & P G Rao<sup>[1]</sup>, North East Institute of Science and Technology (CSIR) investigated the production of grease proof paper from banana pseudo stem. The morphological characteristics of plant and fibre, chemical constituents of the sheath, characteristic of pulp and physical strength properties of hand sheet made from banana pulp alone or in combination with bamboo pulp fibre are presented. And also investigated imparting of grease proof properties by a compound called pentosan (13.5%). The drainage time of banana pulp increases with increase in beating time. The paper made out of this banana pulp showed the characteristics of grease proof paper. The physical strength of the paper can further be improved by incorporating 20% bamboo pulp into banana pulp. Production of pulp and paper on laboratory scale is also presented.

Johansson<sup>[2]</sup> investigated the simplest procedure to determination pentosan content present in various soft and hard woods by using

hydrochloric acid and furfural as main involved chemicals.

Yuan-Shing Perng and Eugene I-Chen Wang<sup>[3]</sup> studied the improvement of grease proof properties by addition of certain chemicals (which acts as fillers, binders and refiners) and by mechanical treatment. Certain calibration curves are also generated for strength of papers for various concentrations of binders, fillers and refiners.

Uraivan Pitimaneeyakul<sup>[4]</sup>, King Mongkut's Institute of Technology Ladkrabang, Thailand investigated the simplest procedure to extract banana fibre from the pseudo stem without damaging the fibre. And also studied various properties related to fibre strength like percentage elongation, moisture regain and fineness. Composition of fibre is also investigated and presented in this literature.

Sunday Albert Lawal and Benjamin Iyenagbe Ugheoke<sup>[5]</sup>, Department of Mechanical Engineering, Federal University of Technology, Nigeria investigated the cellulose content in both hard woods and soft woods and also described available methods to improve the properties of the fibre like scouring etc.,

Shrieves chemical process industries<sup>[6]</sup>, Dryden's outlines of chemical technology<sup>[7]</sup> and Wikipedia provided the information about various pulping methods available today such as Mechanical, Thermo mechanical, Chemical, Chemo thermo mechanical pulping and briefly describing about them like types of Chemical pulping and Chemicals required in both of the process.

## PULPING

Pulping is the process of production of Pulp using wood material which is a lignocelluloses fibrous material. It is prepared by chemically or mechanically separating cellulose fibres from wood, fibre crops or waste paper.

### Raw materials

Generally, woods are two types. Hard woods and Soft woods. Wood from conifers (e.g. pine) is called softwood, and the wood from dicotyledons (usually broad-leaved trees, e.g. oak) is called hardwood. Hard woods are not necessarily hard, and softwoods are not necessarily soft. The well-known balsa (a hardwood) is actually softer than any commercial softwood. Conversely, some soft woods (e.g. yew) are harder than many hardwoods.

These woods contain basically three materials in them. They are:

1. Cellulose
2. Hemi cellulose
3. Lignin, and
4. Pectin

The cellulose present in wood is mostly in the form of fibres. The cellulose fibres are obtained as pulp after pulping process. Cellulose fibre is a long chain of single monomer C<sub>6</sub>H<sub>10</sub>O<sub>5</sub>.

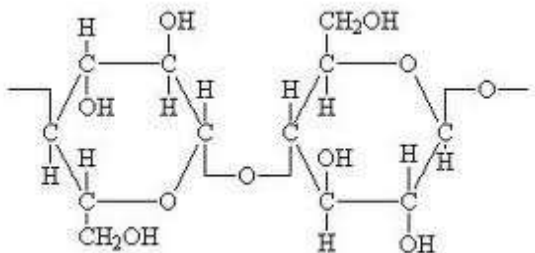


Fig.1: cellulose

Hemi cellulose is made of two compounds, namely Pentosans and Hexosans. The former is responsible for the grease proof properties imparted in the paper.

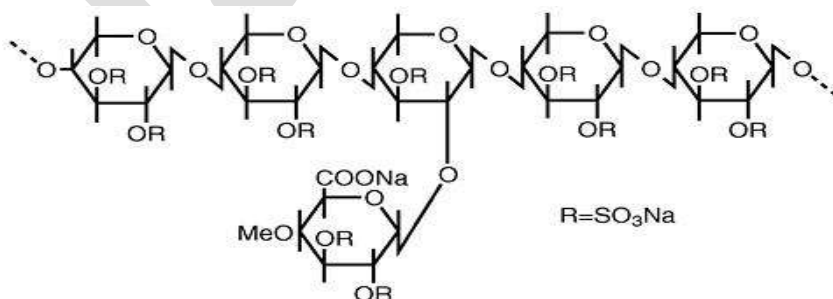


Fig.2: Pentosan structure

In soft woods they are present in about 7-10% where as in hard woods about 19-25%. Lignin and pectin bind the cellulose fibers together in the wood.

The below are the chemical compositions of different woods:

Fibre	Latin name	Cellulose (wt.%)	Hemi-cellulose (wt.%)	Lignin (wt.%)	Pectin (wt.%)
Flax	<i>Linum usitatissimum</i>	60-81	14-18.6	2-3	1.8-2.3
Jute	<i>Corchorus capsularis, C. olitorius</i>	51-72	12-20.4	5-13	0.2
Abaca	<i>Musa textilis</i>	60.8-64	21	12	0.8
Sisal	<i>Agave sisalana Perrine</i>	43-88	10-13	4-12	0.8-2
Kenaf	<i>Hibiscus Cannabinus</i>	36	21	18	2
Ramie	<i>Boehmeria nivea Gaud, variety tenacissima</i>	68.6-76	13.1-15.0	0.6-1	1.9-2
Hemp	<i>Cannabis sativa L.</i>	70-78	17.9-22	3.7-5	0.9
Cotton	<i>Gossypium spp.(commonest G. hirsutum)</i>	82.7-92	2-5.7	0.5-1	5.7
Coir	<i>Cocos nucifera L.</i>	43	0.3	45	4.0
Banana	<i>Musa acuminata L.</i>	60-65	6-19	5-10	3-5
Henequén	<i>Agava fourcroydes Lemaire</i>	60-78	4-28	8-13	3-4
Bagasse	<i>Saccharum officinarum L.</i>	40	30	20	10
Pineapple	<i>Acanas Comosus</i>	80-81	16-19	12	2-2.5
Wood	-	45-50	23	27	-

**Table 1:chemical composition of different woods**  
**INDIAN PULP AND PAPER INDUSTRY**

Indian Paper industry has created sustainable livelihood in rural areas and has helped generating employment for the local population especially for women to earn their livelihood. The Indian Paper Industry has emerged as a diversified and specialized industry that produces numerous types of papers that comes in various use such as watermark, filter paper, drawing sheets, etc. Other products including Paper Bags, paper diaries, paper photo Frames, Greeting Cards, Handmade paper Boxes, paper Albums, etc, are manufactured and exported across the world. Today, the Indian exporters export nearly Rs.400cr. worth of paper products per annum to the developed nations.

The Indian Paper Industry has the top 15 global players with an output of more than 8 million tonnes annually with an estimated turnover of Rs. 200,000 millions. Indian Paper Industry is riding on a strong demand and on an expanding mood to meet the projected demand of 12 million tonnes by 2020.

Indian Paper Industry accounts for about 1.6% of the world's production of paper and paperboard. The estimated turnover of the industry is Rs 25,000 crore (USD 5.95 billion). The industry was delicensed effective from July 1997 by the Government of India & foreign participation is permissible. Most of the paper mills are in existence for a long time and hence present technologies fall in a wide spectrum ranging from oldest to the most modern. Paper in India is made from 40% of hardwood and bamboo fibre, 30 % from agro waste and 30 % from recycled fibre. Newsprint and publication paper consumption account for 2 million tonnes, of which 1.2 million tonnes of newsprint paper is manufactured in India and the remaining 0.8 million tonnes is imported.

Demand of Paper has been around 8% and during the years 2002-07 while newsprint registered a growth of 13% and Writing & Printing, Containerboard, Carton board and others registered growth of 5%, 11%, 9% and 1% respectively. So far, the growth in paper industry has mirrored the growth in GDP and has grown on an average 6-7 % over the last few years. India is the fastest growing market for paper globally and it presents an exciting scenario and paper consumption is poised for a big leap forward in sync with the economic growth and is estimated to touch 13.95 million tons by 2015-16. The futuristic view is that growth in paper consumption would be in multiples of GDP and hence an increase in consumption by one kg per capita would lead to an increase in demand of 1 million tons.

The industry provides employment to more than 0.12 million people directly and 0.34 million people indirectly. Some of the paper products are sheet paper, paper boxes, tissues, paper bags, stationery, envelopes, and printed-paper products such as books, periodicals, and newspapers. Specialty papers like sandpaper, blueprint paper, carbon paper are not a part of paper products industry. Stationery includes greeting cards, printing and writing papers, school and office papers, etc. The toiletry products include paper towels, tissue paper, and bath tissue.

The Rs. 22000-crore paper industry in India, rated 15th largest in world engages about 1.5 million people with the help of Rs. 2500cr Government subsidy. Government has given paper industry as one of the 35 high-priority list.

Indian paper and newsprint industry has a huge potentials and prospects in coming future. In our, country, demand for paper and newspaper is rapidly increasing. There are vast demands in the area of tea bags, filter paper, tissue paper, medical-grade coated paper, lightweight online coated paper, etc.

## METHODS OF PULPING

Many process came into existence for production of pulp from wood materials in past 2 decades. These methods work different because of the feed they take in, based on the quality of pulp obtained after the process and also based on their efficiencies.

### Preparation for pulping

Wood chipping is the act and industry of chipping wood for pulp, but also for other processed wood products and mulch. Only the heartwood and sapwood are useful for making pulp. Bark contains relatively few useful fibres and is removed and used as fuel to provide steam for use in the pulp mill. Most pulping processes require that the wood be chipped and screened to provide uniform sized chips.

### Types of pulping

#### 1. Mechanical pulping:

Manufactured grindstones with embedded silicon carbide or aluminium oxide can be used to grind small wood logs called "bolts" to make stone pulp (SGW). If the wood is steamed prior to grinding it is known as pressure ground wood pulp (PGW). Most modern mills use chips rather than logs and ridged metal discs called refiner plates instead of grindstones. If the chips are just ground up with the plates, the pulp is called refiner mechanical pulp (RMP) and if the chips are steamed while being refined the pulp is called thermo mechanical pulp (TMP). Steam treatment significantly reduces the total energy needed to make the pulp and decreases the damage (cutting) to fibres. Mechanical pulps are used for products that require less strength, such as news print paperboards.

#### 2. Thermo mechanical pulping:

Thermo mechanical pulp is pulp produced by processing wood chips using heat and a mechanical refining movement. It is a two stage process where the logs are first stripped of their bark and converted into small chips. These chips have a moisture content of around 25-30% and a mechanical force is applied to the wood chips in a crushing or grinding action which generates heat and water vapour and softens the lignin thus separating the individual fibres. The pulp is then screened and cleaned; any clumps of fibre are reprocessed. This process gives a high yield of fibre from the timber (around 95%) and as the lignin has not been removed, the fibres are hard and rigid.

#### 3. Chemical pulping:

Chemical pulp is produced by combining wood chips and chemicals in large vessels known as digesters where heat and the chemicals break down the lignin, which binds the cellulose fibres together, without seriously degrading the cellulose fibres. Chemical pulp is used for materials that need to be stronger or combined with mechanical pulps to give product different characteristics. These are of three types mainly:

##### A. Kraft's 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](#) fibres. 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. It involves following operations:

##### Impregnation

Common wood chips used in pulp production are 12–25 millimetres (0.47–0.98 in) long and 2–10 millimetres (0.079–0.39 in) thick. The chips normally first enter the pre-steaming where they are wetted and preheated with steam. Cavities inside fresh wood chips are partly filled with liquid and partly with air. The steam treatment causes the air to expand and about 25% of the air to be expelled from the chips. The next step is to impregnate the chips with black and white liquor. Air remaining in chips at the beginning of liquor impregnation is trapped within the chips. The impregnation can be done before or after the chips enters the digester and is normally done below 100 °C (212 °F). The cooking liquors consist of a mixture of white liquor, water in chips, condensed steam and weak black liquor. In the impregnation, cooking liquor penetrates into the capillary structure of the chips and low temperature chemical reactions with the wood begin. A good impregnation is important to get a homogeneous cook and low rejects. About 40–60% of all alkali consumption in the continuous process occurs in the impregnation zone.

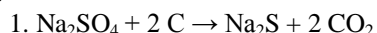
##### Cooking

The wood chips are then cooked in huge pressurized vessels called digesters. Some digesters operate in batch manner and some in continuous processes. There are several variations of the cooking processes both for the batch and the continuous digesters. Digesters producing 1,000 tonnes of pulp per day and more are common with the largest producing more than 3,500 tonnes of pulp per day. In a continuous digester the materials are fed at a rate which allows the pulping reaction to be complete by the time the materials exit the reactor. Delignification requires several hours at 130 to 180 °C (266 to 356 °F). Under these conditions lignin and hemi cellulose degrade to give fragments that are soluble in the strongly basic liquid. The solid pulp (about 50% by weight based on the dry wood chips) is collected and washed. At this point the pulp is quite brown and is known as brown stock. The combined liquids, known as black liquor (so called because of its colour), contain lignin fragments, carbohydrates from the breakdown of hemi cellulose, sodium carbonate, sodium sulphate and other inorganic salts.

##### 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). The combustion is carried out such that sodium sulphate is reduced to sodium sulphide by the organic carbon in the mixture:



This reaction is similar to thermo chemical sulphate reduction in geochemistry.

The molten salts ("smelt") from the recovery boiler are dissolved in process water known as "weak wash". This process water, also known as "weak white liquor" is composed of all liquors used to wash lime mud and green liquor precipitates. The resulting solution of sodium carbonate and sodium sulphide is known as "green liquor", although it is not

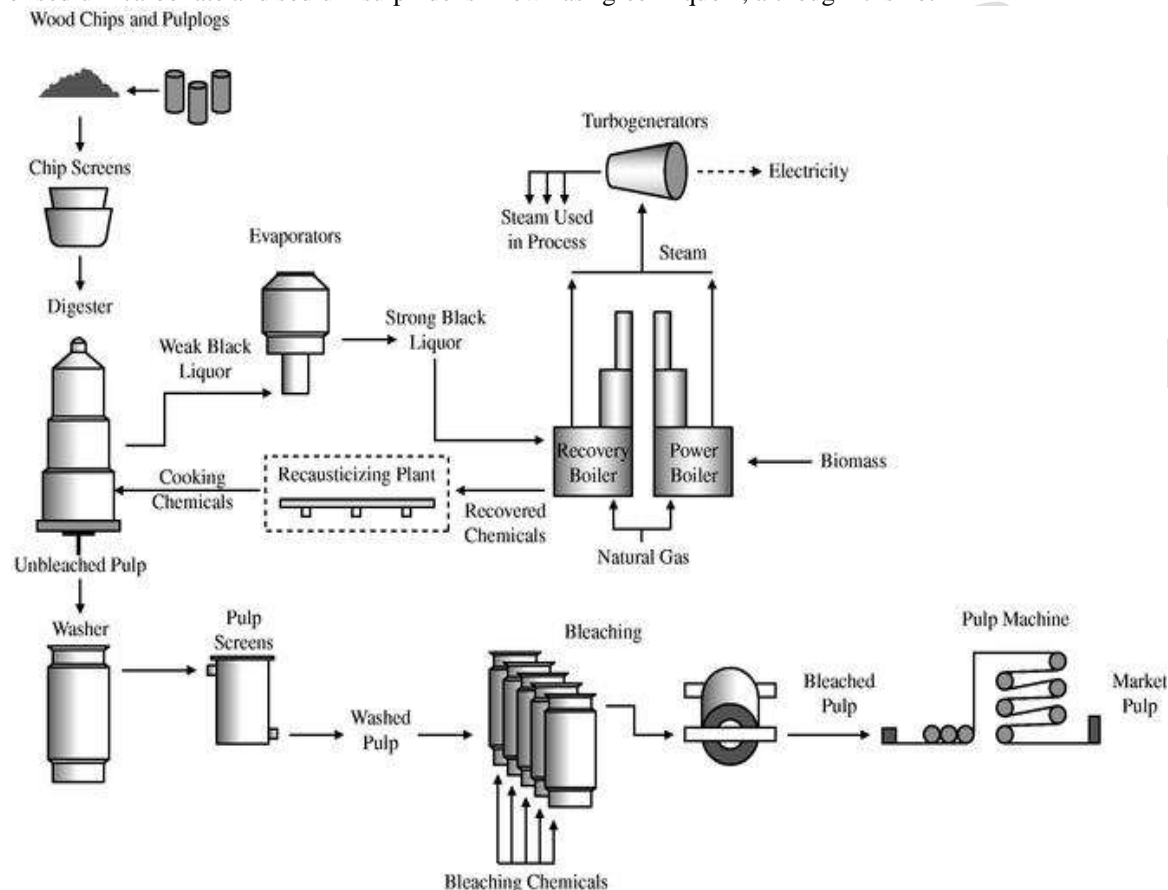
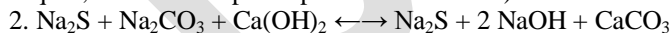
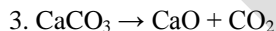


Fig.3:Kraft's process flow sheet

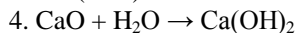
known exactly what causes the liquor to be green. This liquid is mixed with calcium oxide, which becomes calcium hydroxide in solution, to regenerate the white liquor used in the pulping process through an equilibrium reaction ( $\text{Na}_2\text{S}$  is shown since it is part of the green liquor, but does not participate in the reaction):



Calcium carbonate precipitates from the white liquor and is recovered and heated in a lime kiln where it is converted to calcium oxide (lime).



Calcium oxide (lime) is reacted with water to regenerate the calcium hydroxide used in Reaction 2:



The combination of reactions 1 through 4 form a closed cycle with respect to sodium, sulphur and calcium and is the main concept of the so-called re-causticizing process where sodium carbonate is reacted to regenerate sodium hydroxide.

The recovery boiler also generates high pressure steam which is fed to turbo generators, reducing the steam pressure for the mill use and generating electricity. A modern Kraft pulp mill is more than self-sufficient in its electrical generation and normally will provide a net flow of energy which can be used by an associated paper mill or sold to neighbouring industries or communities through to the local electrical grid. Additionally, bark and wood residues are often burned in a separate power boiler to generate steam.

#### Blowing

The finished cooked wood chips are blown by reducing the pressure to atmospheric pressure. This releases a lot of steam and volatiles. The steam produced can then be used to heat the pulp mill and any excess used in district heating schemes or to drive a steam turbine to generate electrical power.

### Screening

Screening of the pulp after pulping is a process whereby the pulp is separated from large Shives, knots, dirt and other debris. The accept is the pulp. The material separated from the pulp is called reject.

The screening section consists of different types of sieves (screens) and centrifugal cleaning. The sieves are normally set up in a multistage cascade operation because considerable amounts of good fibres can go to the reject stream when trying to achieve maximum purity in the accept flow.

The fibre containing shives and knots are separated from the rest of the reject and reprocessed either in a refiner and/or is sent back to the digester. The content of knots is typically 0.5 - 3.0% of the digester output, while the shives content is about 0.1- 1.0%.

### Washing

The brown stock from the blowing goes to the washing stages where the used cooking liquors are separated from the cellulose fibers. Normally a pulp mill has 3-5 washing stages in series. Washing stages are also placed after oxygen delignification and between the bleaching stages as well. Pulp washers use counter current flow between the stages such that the pulp moves in the opposite direction to the flow of washing waters. Several processes are involved: thickening / dilution, displacement and diffusion. The dilution factor is the measure of the amount of water used in washing compared with the theoretical amount required to displace the liquor from the thickened pulp. Lower dilution factor reduces energy consumption, while higher dilution factor normally gives cleaner pulp. Thorough washing of the pulp reduces the chemical oxygen demand (COD).

Several types of washing equipment are in use:

- Pressure diffusers
- Atmospheric diffusers
- Vacuum drum washers
- Drum displacers
- Wash presses

### Bleaching

In a modern mill, brown stock (cellulose fibres containing approximately 5% residual lignin) produced by the pulping is first washed to remove some of the dissolved organic material and then further delignified by a variety of bleaching stages.

The pulp produced up to this point is still in brown colour due in the process can be bleached to produce a white paper product. The chemicals used to bleach pulp have been a source of environmental concern, and recently the pulp industry has been using alternatives to chlorine, such as chlorine dioxide, oxygen, ozone and hydrogen peroxide.

In the case of a plant designed to produce pulp to make brown sack paper or linerboard for boxes and packaging, the pulp does not always need to be bleached to a high brightness. Bleaching decreases the mass of pulp produced by about 5%, decreases the strength of the fibres and adds to the cost of manufacture.

### Pulp bleaching

The dark colour of the pulp is mainly due to residual lignin.  
This is removed gradually during bleaching.

After cooking      O<sub>2</sub>      Bleaching



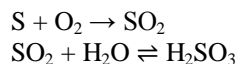
**Fig.5: Bleaching of pulp**

#### A. Sulphite process:

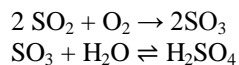
The sulphite process produces wood pulp which is almost pure cellulose fibres by using various salts of sulphurous to extract the lignin from wood chips in large pressure vessels called digesters. The salts used in the pulping process are either sulfites (SO<sub>3</sub><sup>2-</sup>), or bisulphites (HSO<sub>3</sub><sup>-</sup>), depending on the pH. The counter ion can be Sodium, Calcium, Magnesium or Ammonium.

#### Pulping liquor preparation

The pulping liquor for most sulphite mills is made by burning sulphur with the correct amount of oxygen to give sulphur dioxide, which is then absorbed into water to give sulphurous acid.

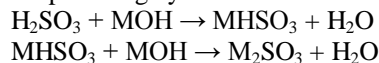


Care must be taken to avoid the formation of sulphur trioxide since it gives undesired sulphuric acid when it is dissolved in water.

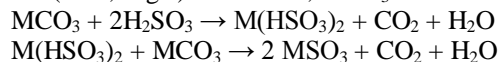


Sulphuric acid is undesirable since it promotes hydrolysis of cellulose without contributing to delignification.

The cooking liquor is prepared by adding the counter ions as hydroxides or carbonates. The relative amounts of each species present in the liquid depend largely on the relative amounts of sulphurous used. For mono valent ( $\text{Na}^+$ ,  $\text{K}^+$  and  $\text{NH}_4^+$ ) hydroxides, MOH:



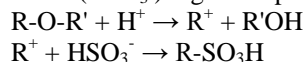
For divalent ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ) carbonates,  $\text{MCO}_3$ :



### Pulping process

Sulphite pulping is carried out between pH 1.5 and 5, depending on the counter ion to sulphite (bisulphite) and the ratio of base to sulphurous acid. The pulp is in contact with the pulping chemicals for 4 to 14 hours and at temperatures ranging from 130 to 160 °C (266 to 320 °F), again depending on the chemicals used.

Most of the intermediates involved in delignification in sulphite pulping are resonance-stabilized carbocations formed either by protonation of carbon-carbon double bonds or acidic cleavage of ether bonds which connect many of the constituents of lignin. It is the latter reaction which is responsible for most lignin degradation in the sulphite process. The electrophilic carbocations react with bisulphite ions ( $\text{HSO}_3^-$ ) to give sulphonates.



The sulphite process does not degrade lignin to the same extent that the Kraft's process does and the lignosulfonates from the sulphite process are useful by products.

### Chemical recovery

The spent cooking liquor from sulphite pulping is usually called brown liquor, but the terms red liquor, thick liquor and sulphite liquor are also used (compared to black liquor in the Kraft process). Pulp washers, using counter current flow, remove the spent cooking chemicals and degraded lignin and hemi cellulose. The extracted brown liquor is concentrated, in multiple effect evaporators. The concentrated brown liquor can be burned in the recovery boiler to generate steam and recover the inorganic chemicals for reuse in the pulping process or it can be neutralized to recover the useful by products of pulping.

The sulphite process can use calcium, ammonium, magnesium or sodium as a base.

### Calcium-based

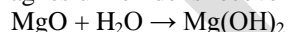
The earliest process used calcium, obtained as inexpensive calcium carbonate and there was little incentive to recover the inorganic materials.

### Ammonia-based

Ammonia-based processes do not allow recovery of the pulping chemicals since ammonia or ammonium salts are oxidized to nitrogen and nitrogen oxides when burned.

### Magnesium-based

The recovery process used in magnesium-based sulphite pulping the "Magnefite" process is well developed. The concentrated brown liquor is burned in a recovery boiler, producing magnesium oxide and sulphur dioxide, both of which are recovered from the flue gases. Magnesium oxide is recovered in a wet scrubber to give slurry of magnesium hydroxide.



from the flue gases producing a magnesium bisulphite solution that is clarified, filtered and used as the pulping liquor.



### Sodium-based

Sodium-based processes use a recovery system similar to that used in the Kraft, except that there is no "lime cycle".

### Applications

The sulphite process is acidic and one of the drawbacks is that the acidic conditions hydrolyze some of the cellulose, which means that sulphite pulp fibres are not as strong as Kraft pulp fibres. The yield of pulp (based on wood used) is higher than for Kraft pulping and sulphite pulp is easier to bleach.

#### B. Soda pulping:

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  $\text{Na}_2\text{CO}_3$  are used. The quality of pulp obtained in soda pulping is low and used for manufacturing low grade paper.

The amount of bleaching agent required is large as the lignin content is not effectively removed.

#### 4. Chemo thermo mechanical pulping:

Wood chips can be pre-treated with sodium carbonate, sodium hydroxide, sodium sulphite and other chemicals prior to refining with equipment similar to a mechanical mill. The conditions of the chemical treatment are much less vigorous (lower temperature, shorter time, less extreme pH) than in a chemical pulping process since the goal is to make the fibres easier to refine, not to remove lignin as in a fully chemical process. Pulps made using these hybrid processes are known as chemo thermo mechanical pulps (CTMP).

#### 5. Recycled pulp:

Recycled pulp is also called deinked pulp (DIP). DIP is recycled paper which has been processed by chemicals, thus removing printing inks and other unwanted elements and freed the paper fibres. The process is called deinking.

DIP is used as raw material in papermaking. Many newsprint, toilet paper and facial tissue grades commonly contain 100% deinked pulp and in many other grades, such as lightweight coated for offset and printing and writing papers for office and home use, DIP makes up a substantial proportion of the furnish.

#### 6. Organosolv pulping:

Organosolv pulping uses organic solvents at temperatures above 140 °C to break down lignin and hemi cellulose into soluble fragments. The pulping liquor is easily recovered by distillation.

#### Market pulp:

It is any variety of pulp that is produced in one location, dried and shipped to another location for further processing. Important quality parameters for pulp not directly related to the fibres are brightness, dirt levels, viscosity and ash content.

##### 1. Air dry pulp

Air dry pulp is the most common form to sell pulp. This is pulp dried to about 10% moisture content. It is normally delivered as sheeted bales of 250 kg. The reason to leave 10% moisture in the pulp is that this minimizes the fibre to fibre bonding and makes it easier to disperse the pulp in water for further processing to paper.<sup>[22]</sup>

##### 2. Roll pulp

Roll pulp or reel pulp is the most common delivery form of pulp to non traditional pulp markets. Fluff pulp is normally shipped on rolls (reels). This pulp is dried to 5 - 6% moisture content.

##### 3. Flash dried pulp

Some pulps are flash dried. This is done by pressing the pulp to about 50% moisture content and then let it fall through silos that are 15–17 m high. Gas fired hot air is the normal heat source. The temperature is well above the char point of cellulose, but large amount of moisture in the fibre wall and lumen prevents the fibres from being incinerated. It is often not dried down to 10% moisture (air dry). The bales are not as densely packed as air dry pulp.

#### Paper production:

In some industries paper production continues after the pulp production rather than storing it as market pulp and exporting it.

In such industries the presence of fourdrinier machine is common for production of paper. It is simply a machine that consists of series of rollers which work on the principles of pressure and heat.

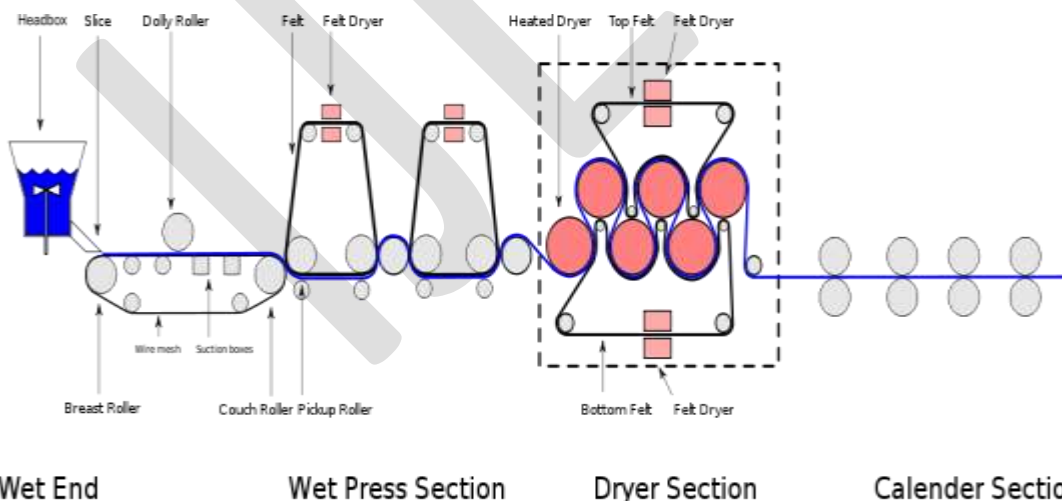


Fig.6: fourdrinier machine

#### MATERIALS AND CHEMICALS

#### Why Banana Plant?

Banana is one of the rhizomatous plants and currently grown in 129 countries around the world. It is the fourth most important global food crop. Different parts of banana trees serve different needs, including fruits as food sources, leaves as food wrapping,



and stems for fibre and paper pulp.

Banana is an important fruit crop which belongs to the genus *Musa*. It grows wild and also cultivated on a large scale as a field crop as well as a backyard crop in households. In India, banana is cultivated in about 1,86,000 hectare of land. The plant shows luxuriant growth in rich well-drained soil with ample moisture and decaying organic matter. It can also flourish on light sandy or gravelly soil as well as on stiff but well drain clay, if the soil is fertile and facilities for irrigation are available.



**Fig.6: Banana pseudo stem**

The pseudo stem portion of the plant contains fibre suitable for making ropes and twines. Extraction of certain species of banana fibre and its industrial application has also been reported. The fibre is located primarily adjacent to the outer surface of the leaf sheath. Well cleaned and brushed decorticated whole leaf sheath yield 80-85% long (4-6 mm), slender (mean width 17-21  $\mu\text{m}$ ) fibres.

Greaseproof paper is a type of non-absorbent paper that is impermeable to oil or grease and can be used for various purposes in the kitchen like layering fragile foods, wrapping food for storage and for lining cake tins. It is suitable for use in fridges, freezers and microwave ovens. It can be used to line baking trays, to wrap foods for packed lunches and to wrap fatty foods such as butter, cheese, smoked fish, cold meats and salami. Use of greaseproof paper to make jam pot covers and lids for separating food into individual portions for freezing is also reported. Grease proof paper is made from wood pulps which are highly hydrated so that the resulting paper is resistant to oil and grease. The timber resources used to make wood pulp are referred to as pulp wood. Wood pulp generally comes from softwood trees such as spruce, pine, fir, larch, and hemlock, and also some hardwoods such as eucalyptus and birch.



**Fig.7: Banana fibre**

In recent years, with the growing shortage of wood from the forest, the search for alternative fibre producing plant material has been initiated in many countries of the world. The generation of fast growing high biomass yielding plant is thought to be one of the solutions to meet the shortage of cellulosic material. However, certain agricultural plants producing higher biomass are found to be suitable substitute for certain fibre based industries. Among them banana plant may serve partly as an alternative resource in fibre based industries.

The banana fibres possess good physical strength properties. The higher pentosan content together with gums and mucilage in the sheath of certain species of banana plant may be a suitable source for producing grease proof paper. Although, reports are available on utilization of banana fibre for textile, pulp and paper making, but no reports are available development of greaseproof paper using banana sheath fibre. Considering the higher pentosan, gums and mucilage contents in the sheath of *Musa paradisiaca* plant, a detailed investigation was undertaken to study the possibility of making greaseproof paper from this plant and the results obtained from this investigation are presented in this communication.

**Table 2: Banana fibre properties**

Fibre properties	
Tenacity	29.98 g/denier
Fineness	17.15 denier
Moisture regain	13.0%
Elongation	6.54
Total cellulose	81.80%
Alpha cellulose	61.50%
Residual gum	41.90%
Lignin	15.00%

## CHEMICALS

### Sodium hydroxide

Sodium hydroxide, also known as lye or caustic soda, has the molecular formula NaOH and is highly caustic metallic base. It is a white solid available in pellets, flakes, granules, and as a 50% [saturated solution](#).

Sodium hydroxide is soluble in water, ethanol and methanol. This alkali is deliquescent and readily absorbs moisture and carbon dioxide in air.

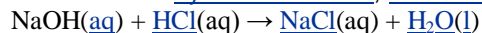
Sodium hydroxide is used in many industries, mostly as a strong [chemical base](#) in the manufacture of [pulp](#) and [paper](#), [textiles](#), [drinking water](#), [soap](#) and [detergents](#) and as a [drain cleaner](#). Worldwide production in 2004 was approximately 60 million [tonnes](#), while demand was 51 million tonnes. Although molten sodium hydroxide possesses properties similar to those of the other forms, its high temperature comparatively limits its applications.

### Physical properties

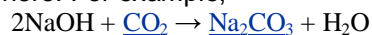
Molar mass	39.997 g/mol
Appearance	White, waxy, opaque crystals
Odour	Odourless
Density	2.13g/cc
Melting point	591 K
boiling point	1661 K

### Chemical properties

Sodium hydroxide reacts with protic acids to produce water and the corresponding salts. For example, when sodium hydroxide reacts with [hydrochloric acid](#), [sodium chloride](#) is formed:



Sodium hydroxide also reacts with [acidic oxides](#), such as [sulphur dioxide](#). Such reactions are often used to "[scrub](#)" harmful acidic gases (like SO<sub>2</sub> and H<sub>2</sub>S) produced in the burning of coal and thus prevent their release into the atmosphere. For example,



### Production:

Sodium hydroxide is industrially produced as a 50% solution by variations of the electrolytic [chloralkali process](#). [Chlorine gas](#) is also produced in this process. Solid sodium hydroxide is obtained from this solution by the evaporation of water. Solid sodium hydroxide is most commonly sold as flakes, [prills](#), and cast blocks.

### Uses:

Sodium hydroxide is the principal strong [base](#) used in the chemical industry. In bulk it is most often handled as an [aqueous solution](#), since solutions are cheaper and easier to handle. Sodium hydroxide, a strong base, is responsible for most of these applications. Another strong base such as [potassium hydroxide](#) is likely to yield positive results as well.

Overall 56% of sodium hydroxide produced is used by the chemical industry, with 25% of the same total used by the paper industry. Sodium hydroxide is also used for the manufacture of sodium salts and detergents, for pH regulation, and for organic synthesis. It is used in the [Bayer process](#) of [aluminium](#) production.

Sodium hydroxide is used in many scenarios where it is desirable to increase the alkalinity of a mixture, or to neutralize acids.

### Sodium carbonate

Sodium carbonate, Na<sub>2</sub>CO<sub>3</sub> is a [sodium salt](#) of [carbonic acid](#). It most commonly occurs as a [crystalline heptahydrate](#), which readily [effloresces](#) to form a white powder, the monohydrate. Sodium carbonate is domestically well known for its everyday use as a [water softener](#). It can be extracted from the ashes of many plants. It is synthetically produced in large quantities from salt ([sodium chloride](#)) and [limestone](#) in a process known as the [Solvay process](#).

### Physical properties:

Molar mass	105.9885 g/mol
Appearance	White solid
Odour	Odourless
Density	2.54 g/cc
Melting point	851 °C
Boiling point	1633 °C

#### Uses:

The manufacture of [glass](#) is one of the most important uses of sodium carbonate. Sodium carbonate acts as a [flux](#) for [silica](#), lowering the melting point of the mixture to something achievable without special materials. This "soda glass" is mildly water soluble, so some [calcium carbonate](#) is added to the pre-melt mixture to make the glass produced insoluble. This type of glass is known as [soda lime glass](#): "soda" for the sodium carbonate and "lime" for the calcium carbonate. Soda lime glass has been the most common form of glass for centuries.

Sodium carbonate is also used as a relatively strong [base](#) in various settings. For example, sodium carbonate is used as a pH regulator to maintain stable alkaline conditions necessary for the action of the majority of photographic [film developing](#) agents.

It is a common additive in municipal pools used to neutralize the acidic effects of [chlorine](#) and raise pH.

In cooking, it is sometimes used in place of [sodium hydroxide](#) for [lyeing](#), especially with [German pretzels](#) and lye rolls. These dishes are treated with a solution of an alkaline substance to change the pH of the surface of the food and improve browning.

In [taxidermy](#), sodium carbonate added to boiling water will remove flesh from the skull or bones of trophies to create the "European skull mount" or for educational display in biological and historical studies.

In chemistry, it is often used as an [electrolyte](#). This is because electrolytes are usually salt-based, and sodium carbonate acts as a very good conductor in the process of electrolysis. In addition, unlike chloride ions, which form chlorine gas, carbonate ions are not corrosive to the anodes. It is also used as a primary standard for acid-base [titrations](#) because it is solid and air-stable, making it easy to weigh accurately.

#### Domestic use:

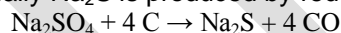
In domestic use, it is used as a water softener in laundering. It competes with the magnesium and calcium ions in hard water and prevents them from bonding with the detergent being used. Sodium carbonate can be used to remove grease, oil and wine stains. It is sold as washing soda, soda crystals, or sal soda. Sodium carbonate is also used as a [descaling](#) agent in boilers such as those found in coffee pots and [espresso machine](#).

#### Sodium sulphide

Sodium sulphide is the [chemical compound](#) with the [formula](#)  $\text{Na}_2\text{S}$ , or more commonly its [hydrate](#)  $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ . Both are colourless water-soluble salts that give strongly [alkaline](#) solutions. When exposed to moist air,  $\text{Na}_2\text{S}$  and its hydrates emit [hydrogen sulphide](#), which smells like rotten eggs. Some commercial samples are specified as  $\text{Na}_2\text{S}\cdot x\text{H}_2\text{O}$ , where a weight percentage of  $\text{Na}_2\text{S}$  is specified. Commonly available grades have around 60%  $\text{Na}_2\text{S}$  by weight, which means that  $x$  is around 3. Such technical grades of sodium sulphide have a yellow appearance owing to the presence of [polysulphides](#). These grades of sodium sulphide are marketed as 'sodium sulphide flakes'. Although the solid is yellow, solutions of it are colourless.

#### Production:

Industrially  $\text{Na}_2\text{S}$  is produced by reduction of [Na<sub>2</sub>SO<sub>4</sub>](#) with carbon, in the form of coal.<sup>[3]</sup>

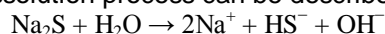


In the laboratory, the anhydrous salt can be prepared by reduction of sulphur with sodium in anhydrous ammonia. Alternatively, sulphur can be reduced by sodium in dry [THF](#) with a catalytic amount of [naphthalene](#):

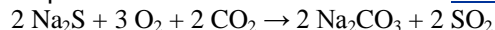


#### Reactions:

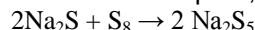
The dissolution process can be described as follows:



Sodium sulphide can oxidize when heated to [sodium carbonate](#) and [sulphur dioxide](#):



Upon treatment with sulphur, polysulphides are formed:



#### Uses:

It is primarily used in [pulp and paper industry](#) in the [Kraft process](#). It is used in water treatment as an oxygen scavenger agent and also as a metals precipitant, in the photographic industry to protect developer solutions from oxidation, in textile industry as a bleaching, as a de-sulphurising and as a dechlorinating agent and in leather trade for the sulphitization of tanning extracts. It is used in chemical manufacturing as a sulphonation and sulphomethylation agent. It is used in the production of rubber chemicals, sulphur dyes and other chemical compounds. It is used in other applications including ore flotation, oil recovery, food preservative, making dyes, and detergent.

Sodium sulphide is an active ingredient in some over-the-counter ingrown toenail relief products.

## EXPERIMENTAL PROCEDURE FOR LAB SCALE PRODUCTION OF PULP

### Preparation of raw material:

1. Initially Banana Pseudo stem is taken and washed several times with water to remove dust and soil particles present on it.
2. Later it is cut into 10 cm long pieces.



**fig:8: banana stem**

3. They are crushed in a sugar cane crusher to remove water content and later dried at 80°C for about 30 minutes to further reduce the water content.



**Fig.9: crushed and dried banana stem pieces**

### KRAFT PULPING:

#### Preparation of cooking liquor

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, Na<sub>2</sub>SO<sub>4</sub>, Na<sub>2</sub>CO<sub>3</sub>. These three chemicals must combine to give total of 12.5% by weight solution.

In this 12.5% of solution, according to Kraft's pulping solids analysis says-

-58.6% is NaOH,

-27.1% is Na<sub>2</sub>SO<sub>4</sub>, and

-14.3% is Na<sub>2</sub>CO<sub>3</sub>

If we take basis as 1000 ml solution of cooking liquor, then 12.5% by weight gives 125gr which is the total weight of all three chemicals required. Compositions of solids are given by wt%. If we calculate the individual weight of chemicals required, they would give the following.

NaOH weight= $.586 \times 125 = 73.25$ gr.

Na<sub>2</sub>SO<sub>4</sub> weight= $.271 \times 125 = 33.875$ gr.

Na<sub>2</sub>CO<sub>3</sub> weight= $.143 \times 125 = 17.875$ gr.

#### 4.2.2. Digesting

Once the cooking liquor is prepared 400ml of it is taken separately in a 100ml beaker to which 5 grams of raw material (dried banana stem) is added and the level is marked. The reason for marking the level is described below.



**Fig.10: cooking liquor and raw material**

Industrially, steam is used for heating purpose. There are two reasons for selecting steam as heating source:

1. Firstly, it would serve as the heating medium for the digester.
2. Secondly, once the steam exchanges heat with the cooking liquor and the raw material the water present in the cooking liquor evaporates due to increase in temperature difference. Then the initial concentration of the cooking liquor is not maintained which would result in weak cooking. So, if steam is used, it condenses into the cooking liquor after exchanging heat, thereby maintaining the concentration of the cooking liquor.

Here, we do not use steam as heating source. If heat is continuously supplied the water present in the cooking liquor evaporates thereby initial concentration of the cooking liquor is varied. To bring back the concentration to initial we add water up to the marked level in the beaker. This is taken care of throughout the process of digesting.

The heat is supplied by means of hot plate for about 4hr 30min at a temperature of 90°C. At the same time stirring is done continuously throughout the process.



**Fig.11: brown stock and black liquor**

In the process of digestion the strong basic cooking liquor and the action of heat combine and help breaking the bonds in lignin molecules. The broken lignin molecules dissolve in cooking liquor thereby turning it into dark brown color called as Black liquor and cellulose remaining unaltered is present in the cooking medium as brown stock along with the traces of lignin.

#### **SODA PULPING:**

##### **Preparation of cooking liquor**

In this process, 20% by weight solution of NaOH is required as cooking liquor.

If we take 1000ml as basis 20% by weight gives 200gr of NaOH. These 200 grams of NaOH is dissolved in water and makeup to 1000ml to give required concentration of cooking liquor.

##### **Digesting**

Once the cooking liquor is prepared, 5 grams of raw material (dried Banana stem) is taken in 400ml of cooking liquor in 1000ml beaker and the level is marked.

The reason for the marking the level is already described above in Kraft's process. The same reason applies here too. And water must be added continuously to maintain the initial concentration of the cooking liquor and this process must be repeated entire boiling time.



**Fig.12: cooking**

Next, It is heated to about 90°C (boiling) for 4hr 30min with continuous stirring. But the heat is not enough as the cooking liquor is weak basic compared to Kraft process. So, it is heated for one more hour to increase the effectiveness of heat and cooking liquor in breaking the lignin molecules and dissolving in the cooking liquor.

**Filtration and washing of pulp:**

After digesting, brown stock and black liquor are formed.

Brown stock contains pulp (cellulose and hemi-cellulose) and small amounts of lignin (reason for brown color).



**Fig.13: brown stock and black liquor**

And the black liquor contains the dissolved lignin and cooking chemicals that are unconverted and can be recovered.

The mixture filtered using cloth to obtain black liquor as waste that contains cooking chemicals that can be recovered. One time filtration doesn't remove the lignin traces completely. So, once the filtration is done it is again washed with water to let lignin and chemicals associated with the brown stock to dissolve in it. And, this mixture is again filtered with the cloth and this process is repeated.



**fig.14: washed pulp**

It is washed several times with 1000ml of water to reduce the lignin content (about 5 times).



**Fig.15: filtration**

Finally, the obtained product from the filtration must be in such a way that lignin traces must be less in amounts.

**4.5. Bleaching:**

Once filtration and washing is completed the washed pulp is dissolved in 200ml of water to which 5gr bleaching powder is added to completely remove the brown color to obtain white paper grade pulp.



**Fig.16: bleaching**

**Drying:**

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

**OVERALL VIEW OF THE PROCESS**

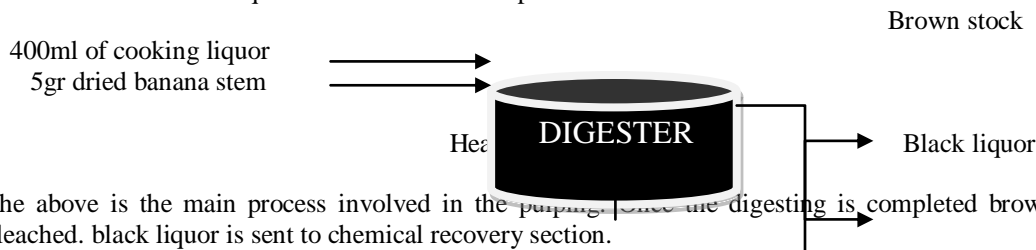
**1. Drying**

Banana pseudo stem after washing with water is crushed in sugar cane crusher is sent into drier.



**2. Digesting**

5 grams of dried Banana stem is taken is sent into beaker along with 400ml of cooking liquor and boiled for 4hr 30min at 90°C. later brown stock and black liquor formed which are separated.



The above is the main process involved in the pulping. Once the digesting is completed brown stock is washed with water and bleached. black liquor is sent to chemical recovery section.

## 5. OBSERVATIONS

Firstly, describing about the heat required for digesting, Kraft process required only 4hr 30min for breaking lignin molecules. But soda process required more heat for digestion and yet could not obtain effective digestion as banana stem material is still present as it is in the beginning on the water cooking liquor surface.

Secondly, Kraft's process consists of strong cooking liquor which can break the lignin more effectively. Where as soda process consist of weak cooking liquor. Because of this reason we can find the traces lignin is more in Soda process than Kraft process.

Product obtained after washing with water is compared in both the processes.



**Fig.17: washed pulp in both Kraft and soda process**

The pulp obtained in Kraft process is less dark in colour than pulp obtained in soda process. The reason for this is, pulp obtained in Kraft process contains less lignin content in it due to the strong basic nature of the solution which breaks the lignin effectively. Soda process involves weak basic cooking liquor that acts weakly in breaking lignin bonds.

At the same pulp obtained after bleaching is also compared.



**Fig.18:soda pulp after bleaching**



**Fig.19: Kraft pulp after bleaching**

The pulp obtained after bleaching is observed and found that Kraft pulp is whiter in colour compared to soda process, as the bleaching agent required to break the traces of lignin is more in the soda process than the Kraft process.

Finally, describing about the yield obtained, the Kraft process gave – 1,735gr of pulp and the Soda process gave – 1.273gr of pulp.

## CONCLUSION:

After experimenting and observing the entire process of operation, there are certain conclusions made and listed below. They are:

1. Though the Soda process requires only one chemical but in large amounts to effectively break the lignin bonds. The Kraft process requires fewer amounts of different chemicals and also helps in complete lignin molecule breakage. From this we can conclude that the Kraft process is more advantageous.
2. In terms of heat requirement the Kraft process is more advantageous, because the cooking liquor is able to break and dissolve the lignin in it. The Soda process is supplied with heat for one hour more and still the cooking liquor could not effectively digest the lignin.



3. 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. Pulp obtained by Soda process can be used for low grade paper production. But the discussion here is 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. By this we can conclude that Kraft process is safer.

4. Finally, 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 is more advantageous.

From the above observations we conclude that Kraft Process is safer and more efficient based on yield.

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I would not have accomplished the work I did with out the support and resources of the above mentioned individuals.

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