WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

A FINAL YEAR PROJECT SUBMITTED TO THE DEPARTMENT OF CHEMICAL ENGINEERING IN WOLKITE UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF SCIENCE (PROCESS STREAM).

UTILIZATION OF BANANA FIBERS FOR MAKING WARPPING PAPER

PREPARED BY:

NAME **ID/NO**

1. **GETACHEW TUFA ………………………..…..ENGR/401/09**
2. **GIRUM TESFAYE ……………………........ENGR/409/09**
3. **SITOTAW ABDULKADIR ………………………ENGR/791/09**
4. **JEMILA FURO ……………………………..……ENGR/480/09**
5. **ABEBECH AREGA ………………………………ENGR/1042/09**

ADVISOR: MR. REMEDAN AHMED

AUGUST 23, 2021

WOLKITE ETHIOPIA

DECLARATION

We declare that this project entitled "Utilization of banana fibers for making wrapping paper"is the result of our own project except cited as in the references.

	Signature	date
Getachew Tufa	------------------------	--------------------
Girum Tesfaye	-----------------------	--------------------
Sitotaw Abdulkadir	----------------------	--------------------
Jemila Furo	----------------------	--------------------
Abebech Arega	----------------------	--------------------

Approved by

	Signature	Date
Advisor: Mr.Remedan Ahmed	-----------------------	--------------------
Internal Examiner:	----------------------	--------------------

ACKNOWLEDGMENT

First and foremost, we would like to extend our infinite thankfulness to almighty GOD for giving us the health, strength and patience throughout the entire situation and challenge that we faced for successful completion of this thesis.

We express our heartfelt gratitude to our thesis advisor, Mr. Remedan A.for his assistance, invaluable comments, suggestions and excellent supervision throughout our thesis work. And also our deepest thanks goes to department head Dr. Gebre E. for your understanding and kind assistance.

We would also to express our deepest and grateful thanks to all laboratory assistance who allowed and assist us to conduct laboratory work. Lastly not the least, we would like to say thank you to all of chemical engineering department staffs for their unlimited cooperation. Our families and the land itself deserve an authentic thankfulness and our heartfelt pray for long lasting peace and prosperity. Let's God bless riches to all!

Table of Content

List of table

List of figure

List of abbreviations

Cp	Specific Heat Capacity
Q	Amount of Heat Needed
FCI	Fixed Capital Investment
TCI	Total Capital Investment
NP	Net Profit
ROI	Return on Investment
DEP	Depreciation
PBP	Payback Period
Wt.	Weight
X_1	Amount of Product Obtained Before Drying
X_2	Amount of Product Obtained After Drying It in Oven
TAPPI	Technical Association of Pulp and Paper Industries
USAID	United States Agency for International Development
USD	United States Dollar
EPPSC	Ethiopian pulp and papers Share Company
NaOH	Sodium Hydroxide
Na_2CO_3	Sodium Carbonate
Na_2S	Sodium Sulphide
H_2O_2	Hydrogen Peroxide

Abstract

Today banana stem is used as a source of raw material for preparation of a pulp and paper. Currently, the dependency of mankind on paper has grown to larger extent because of its wide applications in our day to day activities.Pulp is a lignocellulose fibrous material prepared by chemically or mechanically separating cellulose fibers from wood, fiber crops (banana stem, wheat straw...etc), wastepaper. While Paper can be defined as the crossing network of cellulose fibers bonded to each other. Wood is the primary raw material used to manufacture pulp and paper. But it causes deforestation, so we choosing other alternatives like banana tree waste is the best solution. The reason behind the selection of banana tree waste 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. Therefore, it makes sense to turn such waste into a useful product like pulp by using the concept "from waste to wealth".

The general objective of this project was to produce pulp and wrapping paper from banana tree waste by using Kraft process. In this thesis we have read and observed different Experiments conducted by professionals. The experiments were done in many trial for comparison of the two basic pulping methods i.e. Kraft and soda pulping. The reason to use the Kraft process is that the pulp obtained in Kraft process was less dark in color than pulp obtained in soda process and it was understood that the pulp obtained in Kraft process contain less lignin content in it due to strong basic nature of the solution which break the lignin effectively.

The pulp and wrapping paper production was obtained from banana stem waste by preparation of raw material, debarking, chopping /cutting, digestion, mixing, washing, screening ,paper, making (pressing and Molding) then drying. The pulp and paper production from banana stem was carried out by using stage wise equipment's. We were considering some parameters on the production of pulp like time, concentration of cooking liquor.

The optimum production of pulp was 72.25% at 13.5% white liquor concentration for the cooking time of 4:30 hours, but the maximum mass of pulp was 72.25% at the cooking time of 4:30 minutes with 13.5% white liquor concentration and the minimum mass was obtained 52.5% at minimum concentration (12.5%) and minimum time (5 hour).

Key words: - Kraft pulping,

CHAPTER ONE

INTRODUCTION

1.1 Back ground

Paper manufacturing marks the beginning of the knowledge revolution. 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 newspapers, which is the major revolution in communication that ever happened in the history of mankind. (JayaBharat Reddy Marella, January 2014).

Paper can be prepared from practically any type of fiber, ranging from old jeans to grass clippings (Hayes, ca.2000). It is customarily used for writing, drawing, for printing on or as wrapping material. Garber (2012) stated that tons of paper are produced intentionally for packaging or wrapping. Millions of trees are fell daily since the use of forest sourced fiber has increased considerably recently (Muraleedharan and Perumal, 2010). It then causes the deforestation to be widely spread. Moreover, the pulping process remains using chemical material that is hard to be degraded naturally. The government currently finds it hard to overcome the scarcity of wood as the raw material of paper production in the significant number. As a result, the paper company produces the paper through illegal logging that destroys the nature (JayaBharat Reddy Marella, January 2014). The high number of paper demand causes the need for alternative raw material that is other than wood for wrapping paper industry. The production starts with the process of pulp making. The raw material to produce pulp is the cellulose in the form of fiber in which almost all of the plants contain the cellulose that can be used as the raw material of pulp production. One of the plants containing high cellulose is the banana.

In the banana fields, the pseudo stems and other unused parts are felled and discarded since the banana plant can only be harvested once and the stem often experience fungi attack (Hussain and Tarar, 2014). Clearing the left-overs to plant new crops is a costly procedure for planters (Baldwin, 2016). Usually, the banana plant residues are left on the field to degrade into organic matter since the banana plant cannot provide with fruits more than once (Li et al., 2010).

The degradation of this large waste biomass contributes to greenhouse gas (GHG) emission (CO2) (Hussain and Tarar, 2014). Isolated plant residues often becomes a breeding place for disease vectors (e.g. fruit flies and mosquitoes), which enhances pests proliferation (e.g. rats, snails) and produces bad aesthetic.

Today banana stem is used as a source of raw material for preparation of a paper pulp since it contains very good percentage of cellulose. This pulp is used to prepare different types of paper such as tissue, bloating, tracing and writing printing paper. Banana stems are easily available and cultivates in large scale at the North Eastern and Southern region of Ethiopia. After harvesting, the farmer cuts the banana trees and throws away enormous amount of these stems into the fields because after harvesting the fruit there is no significant use of banana trees. (Ekhuemelo, 2006) Banana trees separate into mainly three parts leaves, stem and roots but the leaves and roots are cut out as it has no use for production of paper. (Jaya Bharat Reddy Marella, January 2014) Cellulose is the main raw material for tissue paper (wrapping paper) and the stem part of banana trees contain the highest percentage of cellulose. (Jokioinen, 1987) When using banana stem for production of pulp we should consider season ability of banana production, the availability of banana stem, its cost and environmental contribution.

Paper is made by pulping wood, bleaching this pulp and then spreading it out into sheets to make it into paper. At various stages of the process, chemicals are used to give the paper particular properties such as the bleaching chemicals that make paper white (and which also enable it to subsequently be colored).

Kraft Pulping along with mechanical puling is the main pulping process used today. (Wiley-Vch Verlag Gmb hand Co.KGaA, 2006.) The Kraft pulping process relies on a combination of heat, chemicals and mechanical Pulping to convert the wood into a smooth, soft pulp suitable for use in paper making.

1.2 Statement of the Problem

Paper is becoming an important commodity of today’s society In Ethiopia the wrapping paper supply is not sufficient for the communities. The pulp and paper industries have been rising due to the increased demand of paper-based products and it is a must to find raw material sources for these industries. The consumption of paper has been also steadily increased over the world.

Wood has been the primary fiber used to manufacture paper and one alternative to reduce Wood is by using banana stem. Although wood is renewable, the rate at which wood has been used is not commensurate with the rate it is being replaced. The rate at which forests are declining has been estimated to be 13.0 million hectares per year in developing countries (FAO UN, 2015). In many developing countries of the world today, wood is becoming scarce and expensive because of the heavy dependence on wood for construction and building purposes, grazing, and conversion of forests to agricultural land to grow crops and felling of tree for firewood.

The government currently finds it hard to overcome the scarcity of wood as the raw material of paper production in the significant number.

In fact, securing adequate raw material to satisfy the increasing paper demand has developed into a serious global environmental issue. Growth in pulp and wrapping paper production entails massive cutting of trees which turns lead to deforestation. Increasing competition for wood supplies coupled with gradually rising costs of wood have generated renewed interest in the use of non-wood plant fibers for wrapping paper making.

In general, this study is important as banana fiber is a widely available and cheap which is best alternative feedstock for paper production and overcomes problems related to environmental issue, promotes rural development through job creation, promotes environmental conservation.

1.3 Objectives

1.3.1 General Objective

The general objective of our study was production of wrapping paper from banana tree fiber

1.3.2 Specific Objectives

The Specific objectives of this study was:

- To characterize the raw material(banana stem fiber)
- To produce pulp from banana stem fiber
- To determine parameters affecting yield of pulp.
- To characterize the pulp produced.

1.4 Significance of the Study

Paper production that is based on agricultural fruit waste offers numerous important environmental and economic advantages over tree based paper production.

Advantages of making paper from agricultural waste particularly banana tree fiber instead of trees includes: protect forests, released fewer toxic chemicals, it is renewable and sustainable, requires less energy, and promotes local paper manufacturing. In addition to this a shift from wood pulp to banana fiber pulp in making paper would take pressure off wild forests and the species that live in them.

So, the rationale of this research work was to investigate the possibility of substitution of banana fiber for imported wood pulp in paper production which could be a good source of raw material to help meeting the Growth and Transformation Plan of the country. Saving foreign currency since the pulp is imported.

1.5 Scope of the project

This project is began from literature review, developing of methodology, performing an experiment to produce pulp and paper from banana stem, calculating material and energy balance, designing and sizing of main equipment for industrial scale, up to economic and feasibility analysis.

1.6 Limitations of the study

During the laboratory analysis there were so many problems like:

- Absence of pressing and molding machine to get the desire paper shape and size.
- Shortage of lab material

CHAPTER TWO

2. LITERATURE REVIEW

Ethiopia has a diverse agro-ecology and sufficient surface and ground water resources, suitable for growing various temperate and tropical fruits. Although various tropical and temperate fruits are grown in the lowland/midland and highland agro-ecologies, the area coverage is very limited. Utilization of banana fiber for producing wrapping paper has been investigated. Banana fiber is a multiple celled structure. Banana is grown in many developing countries and is mainly distributed between North and South latitude. It is the fourth most important food crop in terms of gross value of production. Banana has long been considered a food, fruit and fodder crop. In addition to this, now a day, it is also gaining importance as a source of fibers (Ekhuemelo, 2006). Industries that produce pulp and paper in our country use wood as a raw material (although some of them uses unwanted paper from the society as raw material and recycle it for producing new paper). The conventional paper is derived from wood that is the paper industry is mainly depending upon forest resources, as a result deforestation take place to meet the availability of raw material for paper making industry.

It is broadly accepted that the deforestation causes environmental pollutions and global warming. In recent year, people have placed a high emphasis on forest preservation and rational use of forestry and agriculture residues. Hence, due to harmful effects of deforestation, it is important to search for alternative cellulose containing resources. Studies have shown that the production process of paper from non -wood fiber is significantly less expensive than from wood fiber. (Bandyopadhyay, 2013)

Banana is one of non-wood plant, it contains three main parts. These are root, leaf and stem. Banana fibers obtained from the stem of banana plant have been characterized for their diameter variability and their mechanical properties, with a stress on fracture morphology. The banana stem, grain stalk that supports the banana fruits, is normally discarded after the fruit harvesting, either in the packing house or in the delivering centers where it is considered a residue due to the great volume generated.

These non-woods contain basically three materials in them. They are: Cellulose, Hemi cellulose, and Lignin. The cellulose present in non-wood is mostly in the form of fibers.

The cellulose fibers are obtained as pulp after pulping process. Pulping is the process of production of Pulp using wood material which is a lignocelluloses fibrous material. Pulping of these fibers may be performed by mechanical means at high temperatures or using a modified Kraft or soda process. (Jaya Bharat Reddy Marella, January 2014). Non wood fibers can reduce the amount of chemicals needed for pulping as well as shorten time, thus saving energy. Non wood plants are wheat straw, rice straw, banana fiber and other.

Paper and fiber-based products play important roles in our daily lives. The increasing demands and the requirements of these paper and products are in line with the increasing of human population, their quality of life and the country's rapid development and progresses. Paper can be defined as the crossing network of cellulose fibers bonded to each other (Edward, F.T, 1982). Paper is used for writing and printing, for wrapping and packaging, and a variety of other applications ranging from kitchen towels to the manufacture of building materials. In modern times, its production in large quantities has been a significant factor in the increase in literacy and the raising of educational levels of people throughout the world (Wiley-Vch Verlag Gmb hand Co.KGaA, 2006). Paper production is mainly a two-step process in which a fibrous raw material is first converted into pulp, and then the pulp is converted into paper. The harvested banana stem is first processed so that the fibers are separated from the unusable fraction of the stem, the lignin. Pulp making can be done mechanically or chemically.

2.1 Banana

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 fiber and paper pulp. (Jaya Bharat Reddy Marella, January 2014).

Banana trees have three parts. Those are:-

- Leaves,
- stem and
- roots

Figure 1: Banana trees

In our case from among three parts of banana trees leave and roots are cut out at has not use for preparation of pulping paper because stem parts contain highest percentages of cellulose.

Table 1: The chemical properties of banana stem

Properties	Go swami et al., 2008	Bilba et al.,2007	Kumar ,2011
Lignin (%)	17.25-18.21	15.07	11.0
Cellulose (%)	57.8-62.2	31.27	43.6
Hemicellulose (%)	15.2-17.5	14.98	-
Ash (%)	1.6-2.5	8.68	7.1

Banana fibers

Banana fiber is the best natural fiber. It has its own physical and chemical characteristics and many other properties that make it a fine quality fiber.

Banana fiber is the best natural fiber. It has its own physical and chemical characteristics and many other properties that make it a fine quality fiber.

- Appearance of banana fiber is similar to that of bamboo fiber and ramie fiber, but its fineness and spin ability is better than the two.
- The chemical composition of banana fiber is cellulose, hemicellulose, and lignin.
- It is highly strong fiber.

- It has smaller elongation.
- It has somewhat shiny appearance depending upon the extraction & spinning process.
- It is light weight.
- It has strong moisture absorption quality. It absorbs as well as releases moisture very fast.
- It is bio- degradable and has no negative effect on environment and thus can be categorized as eco-friendly fiber.
- It can be spun through almost all the methods of spinning including ring spinning, open-end spinning, best fiber spinning, and semi-worsted spinning among.

Compositions of Banana Fibers

Lignin The main component of non-wood that needs to be removed to turn it into paper is a compound Known as lignin. Lignin is the reinforcing compound that is deposited on tree cell walls to make the non-wood strong enough to carry the weight of the banana tree crown. However, it is also the compound that makes non wood pulp brown, so it is removed from all non-wood pulp except that used to make wrapping paper.

Cellulose: - The cellulose present in non-wood is mostly in the form of fibers**.** The cellulose fibers are obtained as pulp after pulping process.

2.2 Paper and pulp

Paper and fiber-based products play important roles in our daily lives. The increasing demands and the requirements of these paper and products are in line with the increasing of human population, their quality of life and the country's rapid development and progresses. Paper can be defined as the crossing network of cellulose fibers bonded to each other. Until recently, there are various criteria for paper produced in accordance with the requirements of the users (A.smook., Gary,1992)

2.3 Production and Consumption of Pulp and Paper in Ethiopia

Ethiopian pulp and papers Share Company was the firs**t** paper manufacturing industry, established and gets legal recognition in August 29, 1955 E.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 1962 the total expenses were 22 million birr and at the same time its capital was pumped to 10 million birr.

During its establishment the company produces paper product of 25 ton daily and 8,500 ton annually. According to the study made in 2006, EPPSC has got a 38% market share in corrugated box and 25% market share in wrapping paper. The factory has opened job opportunity for 684 employees out of which 534 are permanent and 150 are contract. In addition to that EPPSC has organized more than 158 youths in association for the processing and supplying of recyclable paper.

Currently in Ethiopian there are about 25 companies that are involved in paper making, packaging and trading businesses i.e. two governments owned, four share company and the rests are owned privately. But only two factories namely the Ethiopian pulp and paper share company and Barguba private limited company, are manufacturing paper products and covering a limited amount of local demands for the product (ECCIDI, 2016).

Table 2: Pulp processes and paper converting industries in Ethiopia.

No.	Company Name	Designed Capacity (ton per yr.)	Attainable capacity (ton per yr.)	Product Type
		Government owned		
1	Ethiopia Pulp & Paper S.C*	16000	6000	Printing and Writing Paper, Stationery Paper, Paper board, Corrugated Box,

2	Anmol Products Ethiopia PLC	14000	12000	Printing, writing papers Wood free and manila papers…etc.
3	Addis Ababa Cement Bag Factory			
		Share Company		
1	Yekatit Paper Converting Enterprise	1600	1400	paper products
2	Tana Pulp & Paper S. Co.*			
		Private Limited company		
1	DA packaging plc.	up to 10,000	2000	Kraft liners, test liners, fluting papers etc.
2	Barguba Trading P.L.C	up to 10,000		paper products
3	Three sisters pulp and paper manufacturing enterprise	10000	1500	Kraft liners, test liners, fluting papers etc.
4	Suzo plc.	2000	2000	Roll papers for wrapping manufacturers

5	Mamco Paper Products Factory Plc.			Paper products
6	Moab Paper P.L.C			Paper products
7	Nice Paper			Paper products
8	Mohammed Mohasin Ahmed paper products			Paper products
9	Burayu Development PLC (Burayu Paper Industry Industry)*			
10	JMD Overseas*			
11	DA Packaging			
12	Fetlework file folder & packaging plant			
13	Adapty Packaging PLC			
14	Shiv Pack PLC			
16	Minaye Packaging PLC			
18	East Africa Tiger Brands Industry PLC			
20	Unlimited Packaging PLC			

*Companies that are established and undergo expansion projects

**Companies under project and will expected to start in the next five years (ECCIDI, 2016)

Ethiopia as a developing country has significantly very low paper and paper board consumption per capita of 0.43 kilogram /person /year when compared with the world average of 54.48 kilogram/person/year in 2005 (WRI, 2005). The overall amounts of pulp and paper imported and its associated costs in USD for the last nine years, 2011-2020 was presented in table 3, which is obtained from Ethiopian construction inputs and chemicals development institute. Ethiopia has imported 51,388 tons of pulp and 844,446 tons of paper with 40.8 and 948.3 million USD for pulp and paper respectively from year, 2011-2020. The average cost in USD per kg was estimated 0.8 for pulp and 1.12 for paper products (ECCIDI, 2016)

Table 3: The quantities imported and associated costs of pulp and paper in Ethiopia from 1909-2020.

Year	Pulp		Paper	
	Quantity (kg)	Cost (USD)	Quantity (kg)	Cost (USD)
2011	4,013,981	2,200,849.781	79,880,956.90	84,651,044.37
2012	1,759,353.89	1,632,848.177	74,798,037.69	82,450,928.73
2013	6,646,105	5,668,217.546	84,172,647.48	101,833,766.21
2014	8,617,781.00	6,759,688.00	101,756,192.18	116,359,837.88
2015	10,216,188.00	8,059,794.46	107,519,199.07	132,301,772.92
2016	5,101,365.00	4,214,596.83	136,955,682.27	127,237,688.80
2017	7,181,482.36	6,025,699.99	108,632,555.78	135,953,748.31
2018	7,852,516.85	6,310,023.24	150,731,302.60	167,529,679.09
2019	8,433,873.69	7,116,245.21	170,745,432.20	181,945.653.42
2020	8,434,654.45	7,246,657,13	173,693,582.07	182,467,578.23

2.4. Type and Classification of paper

Type of paper

Some paper types include:-

- Bank paper
- Banana paper
- Book paper
- Construction paper/sugar paper
- Kraft paper
- Leather paper
- Cotton paper
- Fish paper (vulcanized fibres for electrical insulation)
- Sandpaper
- Wallpaper
- Waterproof paper

Classification of paper

Paper may be classified into three categories

Generally, paper can be classified in to three

1. Cultural paper: which are used in our daily life purpose and includes
   - Newspaper and magazines
   - Books
   - Drawings
   - Cheque paper
   - Poster paper and etc.
2. Industrial papers: papers used for industrial and construction purpose and includes
   - Kraft paper and Sack Kraft
   - Bag-making
   - Wrapping
   - Filter paper
   - Glassine paper and electrical grade.

3. Structural paper: paper used other purposes are usually soft and includes
    - Wall paper
    - Tissue paper
    - Towel paper.

Paper is a thin sheet material produced by mechanically and/or chemical processing cellulose fibers derived from wood, rags, banana stems, grasses other vegetable sources in water by draining the water through fine mesh leaving the fiber evenly distributed on the surface followed by pressing and drying.

2.5. Product Description and Application

Paper is used for writing and printing, for wrapping and packaging, and a variety of other applications ranging from kitchen towels to the manufacture of building materials. In modern times, its production in large quantities has been a significant factor in the increase in literacy and the raising of educational levels of people throughout the world.

The most commonly used paper types are stationary paper (i.e. Printing and writing), news print, wrapping & packaging, and paper card. (Edward, F.T,1982)

2.5.1. Pulp and Paper Making Processing Steps

The pulp and paper making process is carried out in following way steps.

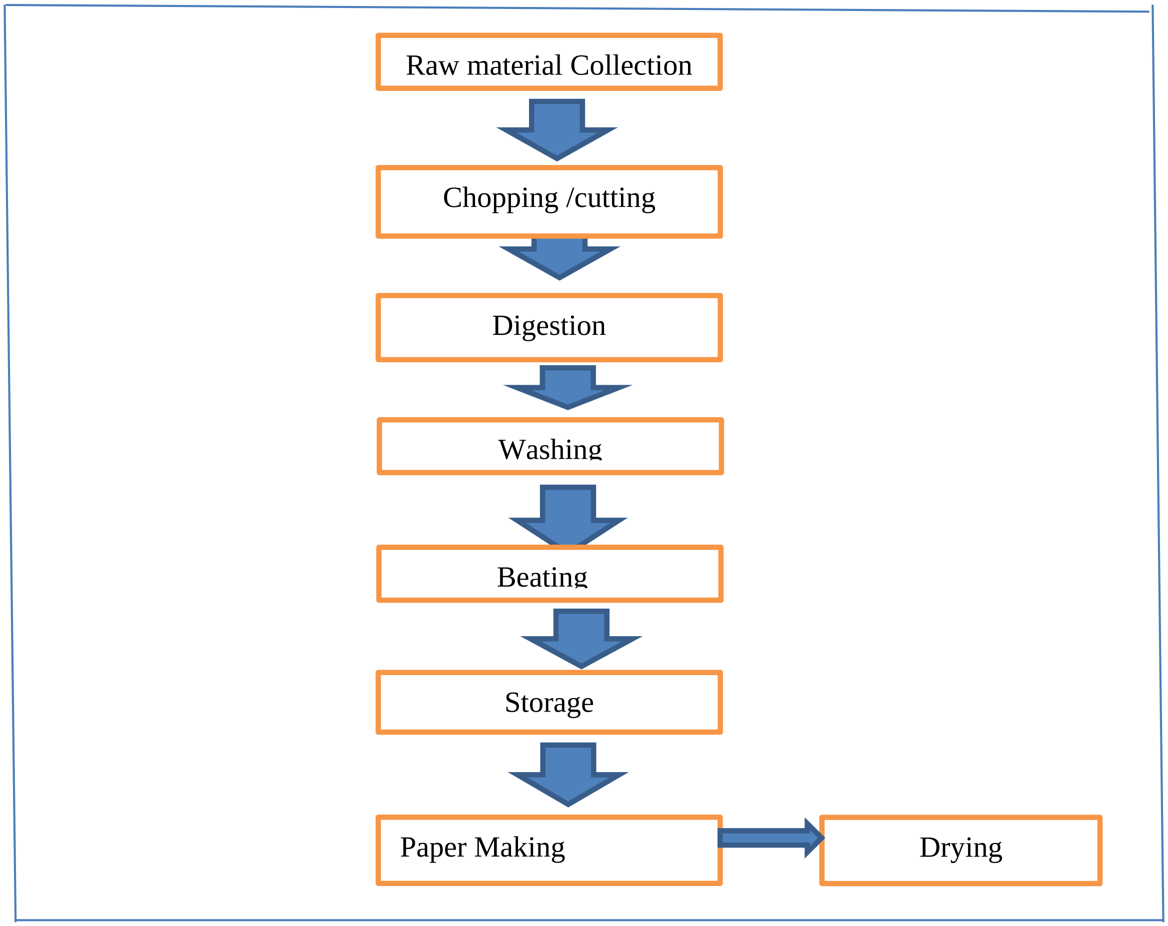


Figure 2: pulps and paper making process

2.5.2. Description of processing steps for pulp and paper making

Raw Material Collection: Banana stem waste, which is thrown away by farmers after harvesting of fruits, is obtained as raw material.

Chopping: The stems are chopped into small pieces of 3-4 inch in size.

Digestion: The material is soaked in 12.5-15% concentration for appropriate period. The alkali loosens the lingo-cellulosic bonds, there by softening the material.

Washing: The softened material is washed with water to remove the black liquor of sodium lignite and unused alkali.

Beating: The washed material is then subjected to beating. Beating is required for a getting good quality pulp, depending upon the quality of boards/paper to be produced.

Storage: After beating, the desired pulp is produced which is then stored in storage tanks.

Paper making: Paper is then making from the pulp of desired quality.

Drying: The wet boards/papers are then allowed to dry.

Flow Sheet for making packaging/Wrapping Paper

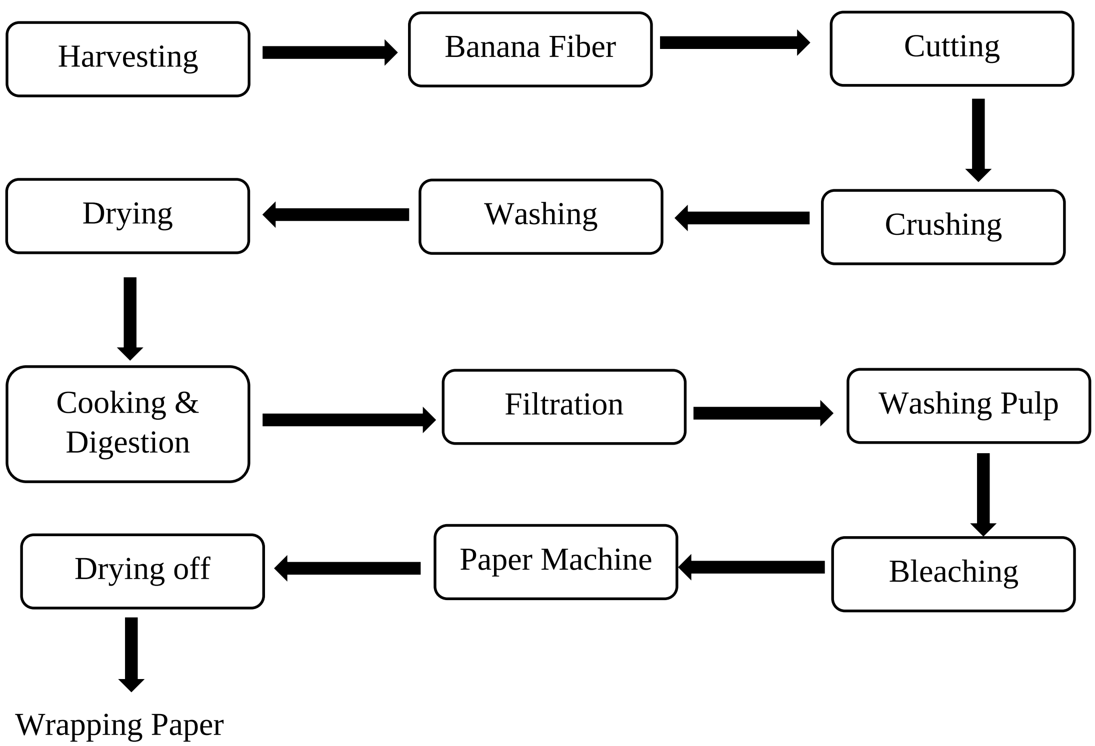


Figure 3: Flow sheet making packaging paper

2.6. Pulping

Pulping is the process of production of pulp using non-stem material which is lingo cellulose fibrous material .It is prepared by chemically or mechanically separating cellulose fibers from non-wood, fibers crops or waste paper. The harvested banana stem is first processed so that the fibres are separated from the unusable fraction of the stem, the lignin.

Pulp making can be done mechanically or chemically. The pulp is then bleached and further processed, depending on the type and grade of paper that is to be produced. In the paper factory, the pulp is dried and pressed to produce paper sheets (Bandyopadhyay, 2013)

2.7 Types of pulping processes

There are three main types of pulping processes:

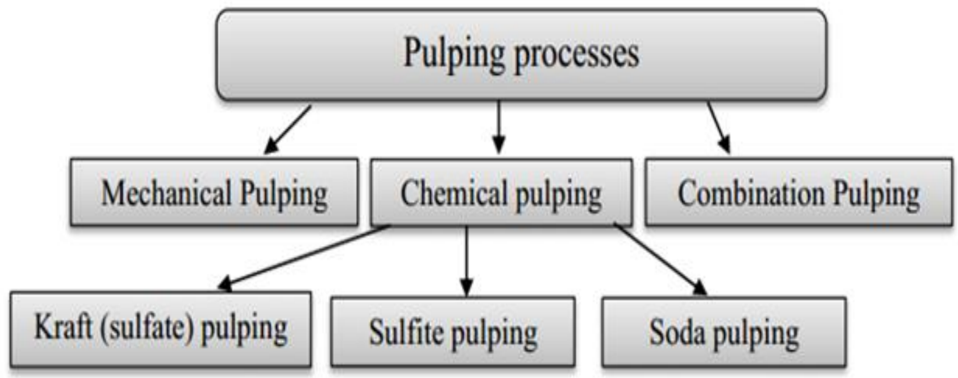


Figure 4: Types of pulping process

2.7.1. 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 fibers together, without seriously degrading the cellulose fibers. Chemical pulp is used for materials that need to be stronger or combined with mechanical pulps to give product different characteristics (Chaudhury J., Singh D.P ,2013)Today chemical pulping is used on most paper and pulp produced company's commercially in the world that is made by cooking (digesting) the raw materials. Chemical pulps are using the sulphate (Kraft) processing and sulphite processes. From the two chemical pulping processes; pulp made by the Kraft (sulphate) process is the dominant process (Wiley-Vch Verlag Gmb hand Co.KGaA, 2006).

A. Pulping by Kraft process

There are several Generally chemical pulping is done by cooking the Banana Stem in a digester (like 5 litres pressure cooker) at high temperature and pressure which dissolve the lignin and leave behind the cellulose. Each pulping trial was carried out on 20 gram of banana stem.

In a conventional Kraft cook, an aqueous solution of sodium hydroxide/sodium sulphide/water, also known as white liquor, is reacted with the raw materials in a pressure vessel called a digester. The white liquor and the banana stem chips are heated to a cooking at approximately 90°C, this Cooking temperature and time are usually for softwood fibers. During this treatment, the hydroxide and hydrosulphide anions react with the lignin, causing variations in cooking process both for the batch and continuous digester. Under high temperature and pressure lignin and Cellulose degrade to give fragments that are soluble in the strongly basic liquid.

The main operations performed in the Kraft pulping process are:

- Digestion of non-wood to form pulp.
- Pulp processing to recover spent cooking chemicals and to remove impurities and uncooked wood chips (deknotting, pulp washing, pulp screening).
- Concentration of used pulping liquor for chemical recovery.

The Kraft process has several advantages:

- It can be used with virtually all non-wood species.
- It can easily handle the extractives in most coniferous wood.
- The pulp has very good strength.
- The recovery process for the chemicals is well established.

However, there are also disadvantages:

- The pulp yield is quite low at about 45 - 50%.
- The equipment used for the chemical recovery is extensive and costly to install.

B. Sulphite processing

The term “sulphate” is derived from the makeup of sodium sulphate chemical, which is added in the pulping process.

In this process almost all wood species used to produce pulp. Lignin can be dissolved by suffocation with an aqueous solution of sulphur dioxide and calcium, sodium, magnesium, or ammonium bisulphite cooked at high temperature and pressure in a digester.

There are four basic sulphite pulping processes currently in commercial use:

1) Acid sulphite,

2) Bisulphite,

3) Neutral sulphite, and

4) Alkaline sulphite.

Sulphite pulping dissolves some of the hemicellulose as well as the lignin. Neutral sulphite pulping, using sodium and ammonium bases, recovers the largest proportion of fiber (75 to 90 percent) of all the sulphite pulping methods.

C. Soda pulping process

Soda pulping is a chemical process for making wood pulp with sodium hydroxide as the cooking chemical. The soda process gives pulp with lower tear strength than other chemical pulping processes (sulphite process and Kraft process), but has still limited use for easy pulped materials like straw.

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 manufacturing Low grade paper. The amount of bleaching agent required is large as the lignin content is not effectively removed (Chaudhury J. Singh D.P ,2013)

2.7.2. Mechanical Pulping

Mechanical pulping is physically tearing the cellulose fibers one from another. Much of the lignin remains adhering to the fibers. Strength is impaired because the fiber may be cut.

There are a number of related hybrid pulping methods that use the combination of chemical & thermal treatment to begin an abbreviated chemical pulping processes, followed by mechanical treatment to separate the fibers. It is used for products that require less strength, such as newsprint and paper board.

Mechanical pulp yields over 90% of the banana stem as fiber is produced by forcing debarked logs, about 2 meters long, and hot water between enormous rotating steel discs with teeth that literally tear the wood apart.

2.7.3. Combination pulping (Semi-chemical Pulping)

Thermo-Mechanical-Pulp (TMP) and hemi-Thermo-Mechanical-Pulp (CTMP) are a combination of the mechanical and chemical processes. De-barked logs are chipped in both, and then heated to extreme temperatures to soften them before passing through refiners for mechanical reduction to fibers. The difference is that chemicals are sprayed onto the chips in the CTMP process to assist with the softening of the chips during refining. The main disadvantage is the high energy demand.

Thermo Mechanical Pulping

The most important refiner mechanical pulping process today is thermo mechanical pulping (TMP). This involves high-temperature steaming before refining; this softens the inter-fibre lignin and causes partial removal of the outer layers of the fibres, thereby baring cellulosic surfaces for inter-fibre bonding.

Thermo mechanical pulping is pulp produced by processing non-wood chips using heat and a mechanical refining movement. It is a two stage processes where the logs are stripped of their bark and converted into small chips.

2.8. Non-wood pulping

Worldwide, non-wood sources make up about 6 % of the total fibre supply for papermaking. Non-wood fibres are derived from agricultural fibres such as straw and other plant fibres such as bamboo, bagasse, and annual fibre crops.

In general, non-wood plant fibres are more costly to collect and process than wood fibre in regions of the world where wood supplies are adequate, and thus pulp is produced almost exclusively from wood fibre in most regions of the world. However, substantial quantities of non-wood pulp are produced.

Most non-wood fibres are relatively short, similar to fibres derived from hardwood, and therefore are suited to similar applications, such as writing paper. However, non-wood fibres are often used for other grades as well, such as newsprint and corrugated board, simply because local wood is not available for pulping. Non-wood species normally cook more readily than wood chips. Thus, Kraft cooking is normally replaced with soda cooking (sodium hydroxide only), and the charge is usually less. The spent liquors usually have lower concentrations of dissolved organics and process chemicals compared with chemical pulping of wood, thus increasing the cost of chemical recovery.

2.9. Pulp washing

The purpose of pulp washing is to obtain pulp that is free of unwanted soluble. In the most basic case, this can be done by replacement of the contaminated liquor accompanying the pulp fibres by clean water. In a modern pulp mill, washing operations include also displacement of one type of liquor by another type of liquor. Aside from its washing function, washing equipment must at times also allow the effective separation of chemical regimes or temperature levels between single fibre line process steps. Various benefits result from pulp washing, such as:

- Minimizing the chemical loss from the cooking liquor cycle
- Maximizing recovery of organic substances for further processing or incineration
- Reducing the environmental impact of fibre line operations
- Limiting the carry-over between process stages
- Maximizing the re-use of chemicals and the energy conservation within a single bleaching stage
- Obtaining a clean final pulp product. Ideally, pulp washing is carried out with the minimum amount of wash water in order to conserve fresh water resources and to take capacity burden from downstream areas which process the wash filtrate.

After pulp production, pulp is processed to remove impurities, such as uncooked chips, and recycles any residual cooking liquor via the pulp washing process. Residual spent cooking liquor from chemical pulping is washed from the pulp using pulp washers.

Efficient washing is very important to maximize return of cooking liquor to chemical recovery and to minimize carryover of cooking liquor (known as washing loss) into the bleach plant, because excess cooking liquor increases consumption of bleaching chemicals. Specifically, the dissolved organic compounds (lignin's and hemicelluloses) contained in the liquor will bind to bleaching chemicals and thus increase bleach chemical consumption (J.M Coulson and J.F Richardson, 2005)

Most pulp washing systems consist of more than one washing stage. The highest washing efficiency would be achieved if fresh water were applied in each stage. However, this approach would require large quantities of water and is, therefore, not used. Counter current washing is the generally used system design. In counter-current washing, the pulp in the final stage is washed with the cleanest available wash water or fresh water before leaving the system. The drained water from this stage is then sent backwards through each of the previous stages in a direction opposite to the pulp flow. The pulp is washed with water to wash out the cooking chemicals and lignin from the fiber so that they will not interfere with later paper making process steps (Chaudhury J. Singh D.P ,2013).

2.10. Pulp screening, cleaning and fractionation, bleaching

Screening of the pulp is done to remove oversized and unwanted particles from good papermaking fibres so that the screened pulp is more suitable for the paper or board product in which it will be used. A sieve is used to remove knots and clumped-together uncooked fibers from the pulp. The biggest oversized particles in pulp are knots. Knots can be defined as uncooked wood particles. The knots are removed before washing and fine screening. In low-yield pulps they are broken down in refiners and/or fiberizes.

The main purpose of fine screening is to remove shives. Shives are small fibre bundles that have not been separated by chemical pulping or mechanical action. Chop is another kind of oversize wood particle removed in screening.

Bleaching

Bleaching of pulp is done to achieve a number of objectives. The most important of these is to increase the brightness of the pulp so that it can be used in paper products such as printing grades and tissue papers. Bleaching is any process that chemically alters pulp to increase its brightness.

Bleached pulps create papers that are whiter, brighter, softer, and more absorbent than unbleached pulps. Bleached pulps are used for products where high purity is required and yellowing is not desired (example printing and writing papers). Unbleached pulp is typically used to produce boxboard, linerboard, and grocery bags. The lignin content of a pulp is the major determinant of its bleaching potential. Pulps with high lignin content (example, mechanical or semi-chemical) are difficult to bleach fully and require heavy chemical inputs. Excessive bleaching of mechanical and semi-chemical pulps results in loss of pulp yield due to fibre destruction.

Bleaching is carried out in a multi-stage process that alternate delignification and dissolved material extracting stages. Additional oxygen- or hydrogen peroxide-based delignification may be added to reinforce the extracting operation. Since its introduction at the turn of the century, chemical Kraft bleaching has been refined into a stepwise progression of chemical reaction, evolving from a single-stage hypochlorite (H) treatment to a multi-stage process, involving chlorine (Cl_2), chlorine dioxide (ClO_2), hydrogen peroxide (H_2O_2) and ozone (O_3).

The bleached pulp is acidified with sulphuric acid or sulphur dioxide to a pH of 5–6. The pulp is treated with NaOH in the presence of O_2. The NaOH removes hydrogen ions from the lignin and then the O_2 breaks down the polymer. Then, the pulp is treated with ClO_2 then a mixture of NaOH, O_2 and peroxide (H_2O_2) and finally with ClO_2 again to remove the remaining lignin and for bleaching (kaj Henricson, professor. August 2004).

Black Liquor Concentration

Residual weak black liquor from the pulping process is a dilute solution (approximately 12-15 % solids) of stem lignin, organic materials, oxidized inorganic compounds (sodium sulphate, sodium carbonate), and white liquor (sodium sulphide and sodium hydroxide).

The weak black liquor is first directed through a series of multiple-effect evaporators to increase the solids content to about 50 % to form “strong black liquor.” The strong black liquor from the multiple-effect evaporators system is either oxidized in the black liquor oxidation system if it is further concentrated in a direct contact evaporator or routed directly to a non-direct contact evaporator, also called a concentrator. Oxidation of the black liquor before evaporation in a direct contact evaporator reduces emissions of odorous total reduced sulphur compounds, which are stripped from the black liquor in the direct contact evaporator when it contacts hot flue gases from the recovery furnace. The solids content of the black liquor following the final evaporator/ concentrator typically averages 65–68 %. The soda chemical recovery process is similar to the Kraft process, except that the soda process does not require black liquor oxidation systems, since it is a non-sulphur process that does not result in total reduced sulphur emissions.

2.11. Pulp Properties

Basic Pulp Properties

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.

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

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 fibre only, so the tendency is to minimize the moisture content of pulp.

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.

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.

2.12. Process Conditions that affect Kraft Pulping

The main variables dealt with in Kraft cooking are: the hydroxide ion concentration, the hydrogen sulphide ion concentration and the ionic strength.

Temperature and liquor-to-wood ratio are also important parameters. The hydroxide ions are consumed during the cooking operation mainly when neutralizing acidic groups in carbohydrates. Hydrogen sulphide ions facilitate the lignin degradation. The ionic strength is detrimental to the pulping reaction rate when it reaches too high concentrations (Maria, April 2007).

2.12.1. Effects of Liquor to banana fiber Ratio

The amount of liquor to fiber (L/F) is an important parameter for uniform and efficient delignification reaction. According to Mortimer (1989) the delignification decreases when the L/F is increased without increasing the Effective Alkali. If the alkali concentration is increased, the total yield decreases (Maria, April 2007).

The liquor to fiber ratio was varied from 8 to 14 and best result was obtained at a liquor to fiber ratio equal to 10 (Akhouri & Kumar, 2015).

When the cooking temperature and cooking time was set at 140 °C and 2hr and 30min. while maintaining the liquor to fiber ratio below 4:1, it is difficult for the ionic liquid, as cooking solvent, to fully infiltrate the straw and dissolve the lignin, resulting in a low pulp yield. When the ratio m (L): m (F) increases, the pulp yield first increases and then decreases. In particular, when the m (L): m (F) is 6: 1, the pulp yield reaches its maximal value. We think that the excessive ionic liquid might damage banana stem fibers. Usually, more ionic liquid leads to more biomass dissolution due to reduction in viscosity and other factors, which means less pulp yield.

Therefore, m (L): m (F) ratio ranging from 9:1 to 6:1 is suitable for pulping (of banana stem fiber) in ionic liquid (Song, Deng, & Zhu, 2016).

2.12.2. Effects of Temperature

The range of cooking temperature for banana fiber in an ionic liquid with a specific liquid- solid m ((L): m (F) from 10: 1 to 4: 1) is 80 -150°C, and the cooking time varies from 4 to 5 hour. The pulp yield increases with the increase in cooking temperature, however, it begins to drop when the cooking temperature is higher than 140°C. Generally speaking, the dissolving capacity of various substances increases with the rise in temperature. Before 140°C, the amount of dissolved lignin increases, which makes beating easy, so pulp yield, is rising.

After 140°C, the pulp yield begins to drop. This means that too high temperatures could damage cellulose in banana stem fiber pulping (Song, Deng, & Zhu, 2016).

2.12.3. Effects of Reaction Time

Reaction time increase leads to completion of reaction. Time increase up to 240 minutes results in lowering of lignin percentage in pulp to a level of 5.7% from 21% which shows a significant change. Further increase of time does not help in delignification (Akhouri & Kumar, 2015).

With the ratio m (L): m(F) 6: 1 and the cooking temperature 140°C, the pulp yield first increases with the increase in cooking time, and then levels off. The pulp yield reaches its highest value when the cooking time is 4 hr. and 30 minute. Banana stem fiber pulping is in the quickly dissolving phase during 2-3 hour, and a number of lignin is dissolved out at this phase. The tendency levels off bit by bit after 4 hour and 30 minute. Theoretically, with longer cooking time, the pulping reaction is more thorough and the delignification is more significant. The cooking time scope of the choice is also based on easy beating and makes pulp yield high. So, with the comprehensive consideration of the pulp yield and benefit, 4-5 hour is selected as the appropriate cooking time. Therefore, we draw a conclusion that the optimum conditions of the pulping process of banana stem fiber can be characterized by a m(L) : m(F) ratio of 6 : 1, a cooking temperature of 100°C, and a cooking time of 4 hour and 30min (Song, Deng, & Zhu, 2016).

2.13. Properties of Paper

Papers are some physical properties involved it properties has been depend upon raw material and processes. The paper sheet can be dried until 65% of relative humidity and it dry for 2 hr. by setting temperature then test various physical strength properties of paper hand sheets. The physical strength properties of hand sheet paper such as tensile strength, bursting strength, double fold, tear index, blister and oil permeability. Physical strength properties of bleached paper made from banana at different angle of freeness and it set by experiment. The banana pulp shows good grease proof properties at 180min.the physical properties of hand sheet paper contains good oil resistance properties for fatty food wrapping, oil and other application to be the better types of papers called grease proof paper.

Porosity: - A low porosity of the base paper is one of the most important requirements to obtain good barrier properties with dispersion coatings.

The porosity of the base paper affects properties such as coating holdout and sorption behaviour. These properties are important when greaseproof is coated with an aqueous coating.

Physical Properties

- High tensile strength.
- In high purity of cellulose in the fiber.
- Low content of lignin.

Basis Weight or Grammage

The basis weight, substance or Grammage is obviously most fundamental property of paper and paperboard. The Basis weight of paper is the weight per unit area. This can be expressed as the weight in grams per square meter (g/m^2), pounds per 1000 sq. ft. of a specific size. Paper is sold by weight but the buyer is interested in area of paper. The basis weight is what determines, how much area the buyer gets for a given weight. Paper maker always strive to get all desired properties of paper with minimum possible basis weight.

Table 4: shows the typical Grammage Values of standard paper sheet.

Grade	**g/m^2**
Cigarette Tissue	22 - 25
Newsprint	40 - 50
Packaging paper	60 -90
Paperboard	120 - 300

Formation

Formation is an indicator of how uniformly the fibers and fillers are distributed in the sheet. Formation plays an important role as most of the paper properties depend on it.

A paper is as strong as its weakest point. A poorly formed sheet will have more weak and thin or thick spots. These will affect properties like caliper, opacity, strength etc.

Paper formation also affects the coating capabilities and printing characteristics of the paper. A poorly formed sheet will exhibit more dot gain and a mottled appearance when printed.

There is no standard method or unit to express formation. It is a relative or subjective evaluation. However when holding paper up to a light source, a well formed sheet appears uniform while a poorly formed sheet has clumps of fibers giving a cloudy look.

Tearing Resistance

Tearing resistance or strengths is a measure of how well a material can withstand the effects of tearing. More specifically it is how well a paper resists or withstands the growth of any cuts when under tension. Tearing resistance indicates the behavior of paper in various end use situations; such as evaluating web run ability, controlling the quality of newsprint and characterizing the toughness of packaging papers where the ability to absorb shocks is essential. Fiber length and inter-fiber bonding are both important factors in tearing strength.

The most commonly used tearing test is T-414, which is often called the Elmendorf tear test, and measures the internal tearing resistance of paper rather than the edge tear strength of paper, which is described in T-470 (Anon, 1987). Internal tearing resistance is a measure of the force perpendicular to the plane of the paper necessary to tear a single sheet through a specified distance after the tear has already been started. Edge tearing strength (T-470) is a measure of the force needed to initiate a tear. The force needed to initiate a tear may be several times the force needed to propagate the tear once it is started. This is commonly known to anyone who has experienced the difficulty of opening a cellophane bag, which, once nicked, tears open easily. Those papers and other film materials that exhibit high tensile stretch or elongation to break also exhibit high edge tearing strength (Caulfield. & Gunderson, 1988). High stretch makes it difficult to localize or concentrate stress in a sufficiently small area so that a tear can be initiated.

The table below contains list of various types of paper, based on their basis weight, based on their end use, process of manufacturing and raw materials used.

Table 5: The major classifications of paper sheets (Lorentzen & Wettre, 2016).

Based on basis weight Tissue: Low weight, <40 g/m^2 Paper: Medium weight, 40 - 120 g/m^2 Wrapping paper: Medium High weight, 120-200 g/m^2 Board: High weight, >200 g/m^2	**Based on Color** Brown: Unbleached White: Bleached Colored: Bleached and dyed or pigmented
Based on Usage Industrial: Packaging, wrapping, filtering, electrical etc. Cultural: Writing, printing, Newspaper, currency etc. Food: Food wrapping, candy wrapping Coffee filter, tea bag etc.	**Based on Raw Material** Wood: Contain fibers from wood Agricultural residue: Fibers from banana stem, grass or other annual plants Recycled: Recycle or secondary Fiber

CHAPTER THREE

3. MATERIAL AND METHODS

3.1 Materials and Equipment

The main raw material that has been used during the experimental works was banana stem which is source of fibers.

Equipment's used to conduct this study were: plastic bag to store raw material, Washer**,** Filter to separate fiber from liquor solution,Digester to cook the banana chips in white liquor (a mix of sodium NaOH sodium carbonate (Na_2CO_3 and sodium sulphide),Dryer, Measuring cylinder to measure the volume of chemicals, Cutter to cut banana stem, Boiler (cooker**)** is to boil the raw material,Balance,Beaker,Screen is removes the remaining oversized particles (fiber bundles and contaminants) from washed pulp… etc.

The chemicals and reagents used in this study were: Sodium hydroxide (NaOH), Sodium carbonate (Na_2CO_3), hydrogen peroxide 3 %(H_2O_2), sodium sulfide (Na2S), distilled water…etc.

3.2 Method

Raw material preparation

Banana stem is the primary raw material used to manufacture pulp, although other raw materials can be used. Pulp manufacturing starts with raw material preparation, which includes debarking (when banana stem is used as raw material), chipping, chip screening, chip handling and storage. Banana stem are cut into desired lengths, followed by debarking, chipping, chip screening, and conveyance to storage.

Chopping/cutting

The stems are chopped into small pieces of size. This step involves the process of size reduction of banana stems for implications of digestion process.

Digesting (Cooking)

The banana stem chips are heated with white liquor in a pressure cooker, during which time a lot of the lignin (the reinforcing substance that make tree cells stem hard and 'woody' rather than soft like those of other plants) is removed from the banana stem. The pressure is then released suddenly, causing the chips to fly apart into fibers.

Washing

After digesting, brown stock and black liquor are removed by water. And to separate fine solid particles from suspension (solid separation).

Screening

Screening of the pulp is done to remove oversized and unwanted particles from good papermaking fibres so that the screened pulp is more suitable for the paper or board product in which it will be used. A sieve is used to remove knots and clumped-together uncooked fibers from the pulp.

Bleaching

The purpose is to increase the brightness of the pulp so that it can be used in paper products such as printing grades and tissue papers. Bleaching is any process that chemically alters pulp to increase its brightness. Bleached pulps create papers that are whiter, brighter, softer, and more absorbent than unbleached pulps. Therefore, pulp is one of important material as the production of paper and wrapping paper to available.

Moulding

Pour pulp mixture into mould and deckle in vats using your fingers to distribute in mould and deckle without touching the mesh.

Paper Drying

Papers were pressed by using atmospheric air to find an edge of the paper and peel it from the dried board. We can place on the table to keep it flat afterwards.

3.3. Experimental Procedure for Lab Scale Production of Pulp and paper

3.3.1. Raw material collection

Banana tree waste was obtained from Gurage zone, cheha woreda, wuchach kebele, since banana is the popular fruits in the specified area.

It was collected in plastic bags and transported to the Wolkite University College of engineering and technology department of chemical Engineering laboratory for wrapping paper production.

Figure 5 Banana Stem

3.2.2. Sample preparation

Sample preparation process include: manual size reduction (scissor cutting), washing and drying after the samples was collected.

- Initially Banana Pseudo stem is taken and washed five times with water to remove dust and soil particles present on it.
- The stem was cut from plant and chopped in small pieces (2–3 inch) and allowed to sun dry for about 3/4 days in the open air. After sun dried, oven dry (OD) measurement was done and the stem was then preparing for cooking.

Figure 6: Sliced and Dried Banana Stem fiber

Raw material characterization

The raw material selection is depending up on the content of cellulose as well as availability of the product relative to energy consumption within cost. So banana stem fiber is one of important material than wood fibers. To compare the chemical composition of banana stem fiber to the wood fibers. Based on the raw material non-wood fiber is better as the production of pulp and to achieve the final products.

This raw material has been low cost and energy consumed as well as environmental friendly better than wood. Banana stem fiber could not be used to animal feed more and also other purposes used so that the farmer thrown away after harvested the banana fruit then to collect the by-product of banana as raw material of paper production. So, if we used this raw material more effective than wood fiber to the production of wrapping paper. The chemical composition of banana fiber is cellulose, hemicelluloses, and lignin.

Therefore banana stem is one of non-wood raw materials it has cellulose and other chemical composition content. Waste Banana stem is a very good source of cellulose. It contains 39.12 % cellulose and 11.34% lignin.

Banana fiber is the best natural fiber. It has its own physical and chemical characteristics and many other properties that make it a fine quality fiber.

- It is highly strong fiber.
- It is light weight.
- It has strong moisture absorption quality. It absorbs as well as releases moisture very fast.
- It is bio- degradable and has no negative effect on environment and thus can be categorized as eco-friendly fiber.

Moisture Content Determination

The chipped banana fiber was made free of moisture in an oven at 105±3 ^{o}C overnight prior to pulping since the moisture content largely affects the pulp yield. Then the moisture content was determined by using the following formula at every two hours interval until constant weight was obtained.

Moisture content = $\frac{W1-W2}{W1} * 100\%$

Where W_1 = Weight of sample before drying

W_2 = Weight of sample after drying it in oven

3.2.3. Pulping By Kraft Processes

Preparation of Cooking Liquor

Preparation of cooking liquor

Kraft pulping consists of following chemicals-NaOH, Na_2SO_4 & Na_2CO_3. 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_2SO_4, and 14.3% is Na_2CO_3. (Jaya Bharat Reddy Marella, January 2014)

If we take basis as 1000 ml solution of cooking liquor, then 12.5% by weight gives 125 g 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 = 0.586 * 125 = 73.25 g.

Na_2S weight = 0.271 * 125 = 33.875 g.

Na_2CO_3 weight = 0.143 * 125 = 17.875 g.

3.2.4. Digesting

Once the cooking liquor is prepared 400ml of it is taken separately in a 1000ml beaker to which 20 grams of raw material (dried banana stem) is added.Hot plate is used for heating purpose.

Figure 7: Cooking

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

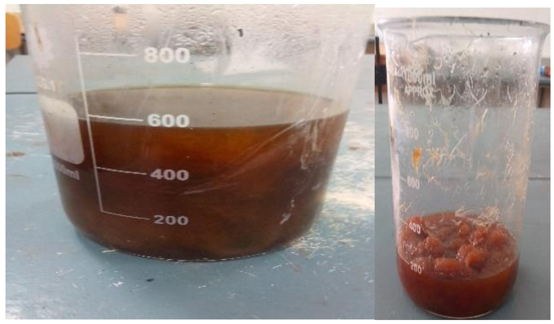


Figure 8: Desired pulps

3.2.5. Filtration and Washing of Pulp:

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 colour).

Figure 9: 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. Washing is the softened material will wash with water to remove the black liquor of sodium lignite and unused alkali. And, this mixture is again filtered with the cloth and this process is repeated.

It is washed several times with 1000ml of water to reduce the lignin content (about 2 times**)**

Figure 10: Washed Pulp

3.2.6. Bleaching

Once filtration and washing is completed the washed pulp is dissolved in 200ml of water to which 5g bleaching agent (hydrogen peroxide H_2O_2) is added to completely remove the brown colour to obtain white paper grade pulp.

Figure 11: Bleached pulp

Determination of moisture content, consistency and the yield of pulp

The pulp obtained after bleaching was observed and found that pulp was whiter in colour compared to digestion process, as bleaching agent required breaking the traces of lignin. Finally the following parameters were compared i.e. moisture content, consistency and the yield obtained

Pulp yield which was expressed as the ratio of moisture free weight of screening pulp from digester with oven dry weight of the chips feed for pulping was determined by the method as per TAPPI (Technical Association of Pulp and Paper Industries) standards

Yield = $\frac{wt\ of\ pulp\ produced}{wt\ of\ original\ banana\ stem} * 100\%$

Moisture content (M.C) = $\frac{x1-x2}{x1} * 100\%$

Where X_1 = Amount of product obtained before drying (wt. of pulp + water = 29.6g)

X_2 = Amount of product obtained after drying it in air (wt. of dried pulp= 11.6g)

Consistency = $\frac{\text{wt of pulp produced}}{\text{wt of pulp+water}} * 100\%$

3.2.7. Drying

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

Figure 12: drying of pulp

3.2.8. Mixing or Blending

Mix or blend to separate fibers in solution (13g pulp at water 600ml use)

3.2.9. Molding Machine

Pour pulp mixture into mold and deckle vats .using your finger to distributing in mold and deckle out touching the mesh.

Figure 13: Paper mould

3.2.10. Pressing Machine

Remove mould and deckle from vat and allow water to drain completely to. Remove deckle by tilting it to the back of the mould. Prepare for pressing into removed excess water.

3.2.11. Paper Drying

Papers were pressed by using atmospheric air. To find an edge of the paper and peel it from the dried board. We can place on the table to keep it flat afterwards.

Figure 14: paper drying

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Experimental results

Experiment One: Kraft Process

The pulp obtained after bleaching was observed and found that pulp was whiter in colour compared to digestion process, as bleaching agent required breaking the traces of lignin. Finally the following parameters were compared i.e. moisture content, consistency and the yield obtained.

Table 6: pulp characterization result

Moisture content of pulp	60.8%
Yield of pulp	58 %
Consistency of pulp	39.2%

Since the consistency is > 15% so, the consistency of the pulp is high

Experiment Two: Comparison with concentration (%) and cooking time (hr.)

The result of all the ten experiments is shown below in table within 100^0C cooking temperature and 20 gram of sample mass.

Table 7: Laboratory experimental results.

	Concentration (%)	Cooking time(hr.)	Dry pulp mass (gram)	pulp yield $= \frac{\text{pulp mass}}{\text{sample mass}} 100\%$
1	12.5	5	10.5	52.5
2	13.5	5	11.5	57.5
3	14.5	5	11.7	58.5

4	12.5	4:45	13.3	66.5
5	13.5	4:45	12.5	62.5
6	14.5	4:45	12	60
7	12.5	4:30	13.34	66.7
8	13.5	4:30	14.5	72.25
9	14.5	4:30	14.24	71.12
10	15	4:20	15.2	76

The optimum production of pulp is 72.25% at 13.5% white liquor concentration for the cooking time of 4:45 hours, but the maximum mass of pulp is 72.25% at the cooking time of 4:30 minutes with 13.5% white liquor concentration and the minimum mass was obtained 52.5% at minimum concentration (12.5) and minimum time (5 hour). From those results, to determine material balance and energy balance as well as to design and size equipment's the optimum pulp yield was selected because from all the 10 results more lignin is removed from the optimum pulp yield.

Maximum pulp production

The maximum pulp production is gained at 13.5% concentration and 4:30 hours cooking time. That means at 13.5% sodium hydroxide, sodium sulphide and sodium carbonate mixture and 4:30 hours cooking time more lignin is removed which is the first experiment of laboratory work.

Minimum pulp production

The minimum pulp production is gained at 12.5% concentration and 5 hour cooking time. That means at 12.5% sodium hydroxide, sodium carbonate mixture, sodium sulphide and 5 hour cooking time small amount of lignin is removed which is the ninth experiment of laboratory work.

Table 8: Summary of results in each unit operations

Unit operations	Amount (g)
Drying	18.8985
Digester	418.8985
Filter	17.6
Washing	17.2
Bleaching	16.34
Drying	12.7

4.2. Discussion

Pulp production experiment from dried banana stem was conduct in nine runs to see the effect of concentration and time on pulp yield using Kraft process. The first experiment was conducted by varying concentration, which is 12.5%, 13.5 %, 14.5% (NaOH, Na_2CO_3 and Na_2S) to 87.5%, 86.5% and 85.5% water concentration respectively for 5 hour residence time, the second experiment was conducted at the same concentration but residence time is 4:45 minute and the third experiment also similar as the above concentration for 4:30 hour of residence time.

The laboratory result was analysed by plotting the graph, time vs. mass of pulp at specified concentration and concentration vs. mass of pulp at specified time as shown below.

Effect of cooking time on mass of pulp

Mass of pulp is affected by cooking time, temperature, concentration, dried banana stem size and other components in the dried banana stem. Concentration of white liquor plays a great role on the mass yield of pulp using Kraft production process. The production rate is fast at the beginning of the production but gets slow gradually. The reason is that when the dried banana stem is cooked to the digester at longer time more lignin is removed beside this, as the cooking time become lower and lower small amount of lignin is removed and at this time a very high concentration of white liquor mixture is required.

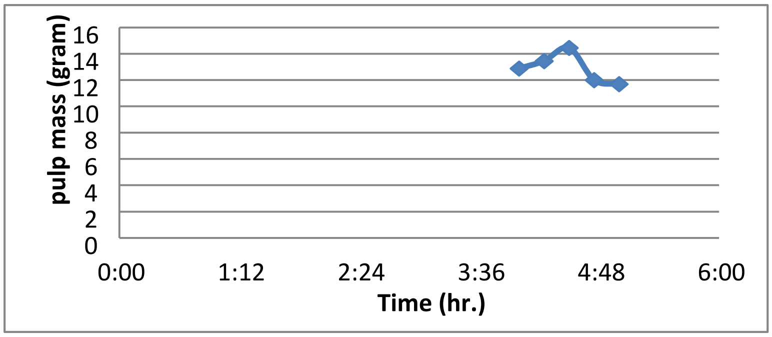


Figure 15: Effect of time on mass of pulp at 12.5% concentration

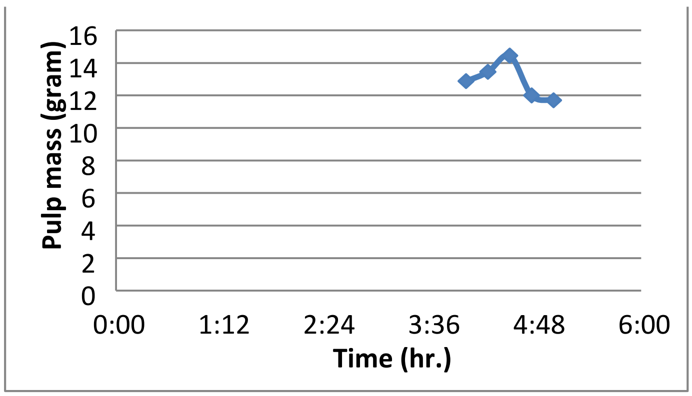


Figure 16: Effect of time on mass of pulp at 13.5% concentration

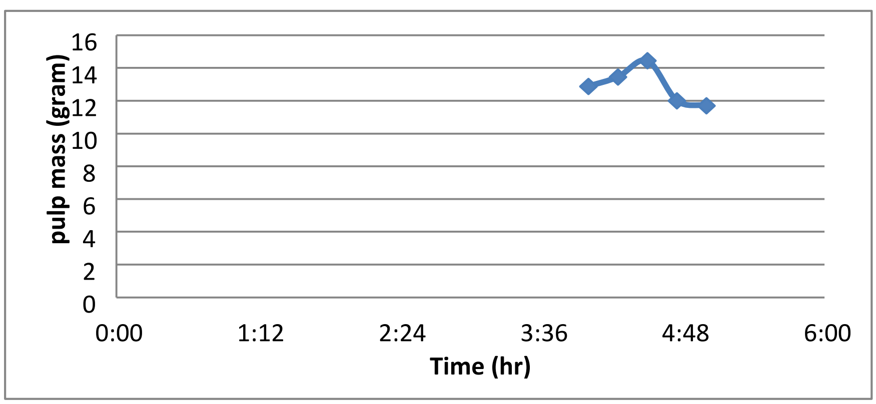


Figure 17: Effect of time on mass of pulp at 14.5.5% concentration

Effect of concentration on mass of pulp

Concentration of white liquor (sodium hydroxide, sodium sulphide and sodium carbonate) plays a great role on the mass yield of pulp using soda production process. As the concentration increase more lignin is removed whereas, when the concentration becomes decreased small amount of lignin is removed and at this time longer cooking time is required to remove lignin.

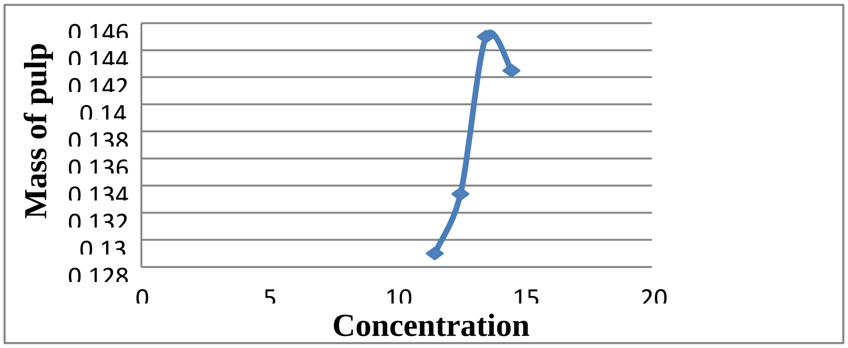


Figure 18 Effect of concentration on mass of pulp at 5 hours

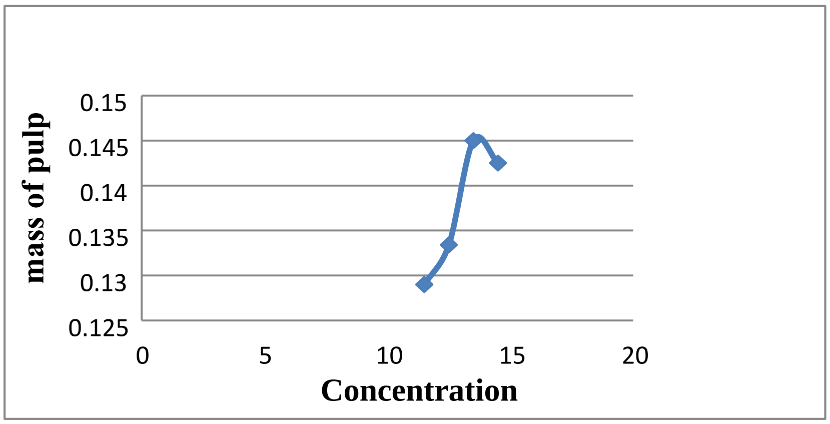


Figure 19: Effect of concentration on mass of pulp at 4:45 hours

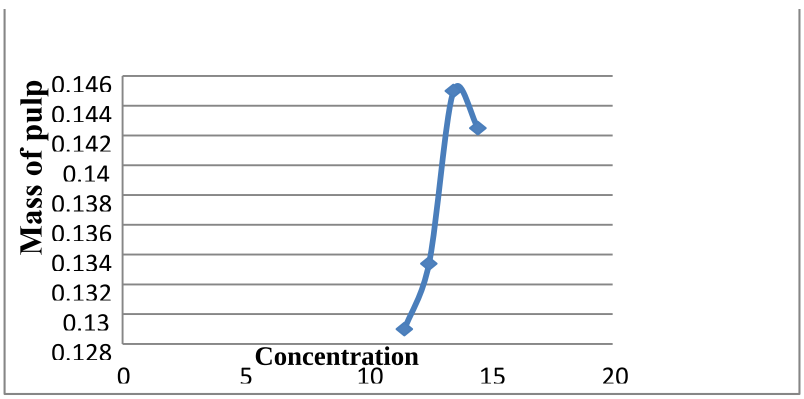


Figure 20: Effect of concentration on mass of pulp at 4:30 hours

CHAPTER FIVE

5. MATERIAL AND ENERGY BALANCE

5.1. Material Balance

Basic Assumptions:

- Steady state for all calculations i.e. Input = output
- Production capacity of the plant is = 3tone/day
- Plant working time is = 320day/year

According to laboratory Experiment two trials two from 20 g of raw material we have produced 12.5g of pulp. Therefore amount of raw material required to produce 3tonne is

Amount of raw material = $\frac{20\ g * 3\ ton/day}{12.5\ g}$ = 4.8 ton/day

Chemicals used in Kraft pulping are NaOH, Na_2SO_4 and Na_2CO_3.

For 20 g of raw material we use so that 400ml of cooking liquor for 4.8tone

Amount of cooking liquor required = $\frac{400\ ml * 4.8\ ton/day}{20\ g}$ = 96 m^3

If we calculate the individual weight of chemicals required, they would give the following.

NaOH weight = $\frac{29.3 * 96}{400}$ = 7.1 ton/day

Water weight = $\frac{400*96}{400}$ = 96 ton/day

Na_2S weight = $\frac{13.55*96}{400}$ = 3.26 ton/day

Na_2CO_3 weight = $\frac{7.15*96}{400}$ = 1.72 ton/day

5.1.1. Chopping

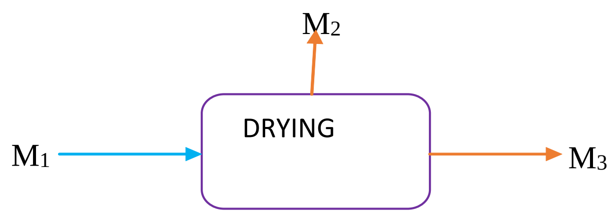
Banana pseudo stem after washing several times with water to remove dust and soil particles present on it is sent to a Chopper to remove some of the water content and reduce its size.

Assumption

Assuming perfect chopping of the Material in=Material out = 4.8 ton of banana stem

5.1.2. Drying

- Banana pseudo stem after washing with water and Chopping is sent into drier.



Where M_1= 4.8 tone of Crushed banana stem dried at 80ºC for 30min

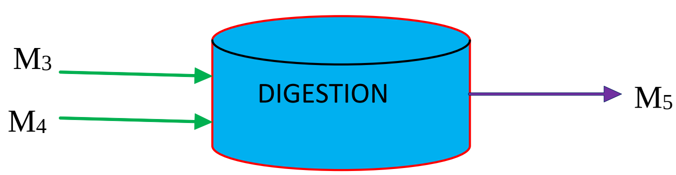
$M_3 = \frac{18.8985\ g * 3\ ton/day}{12.5\ g}$ = 4.55 ton/day of dried banana stem (Refer table :8,Summary of results in each unit Operations).

$M_1 = M_2 + M_3$

$M_2 = M_1 - sM_3 = 4.8 - 4.55 = 0.25m^3$of water removed

5.1.3. Digesting

4.8 tone of dried Banana stem is taken is sent into a digester along with $96m^3$ of cooking liquor and boiled for 4hr and 30min at 100°C. Later brown stock and black liquor is formed.



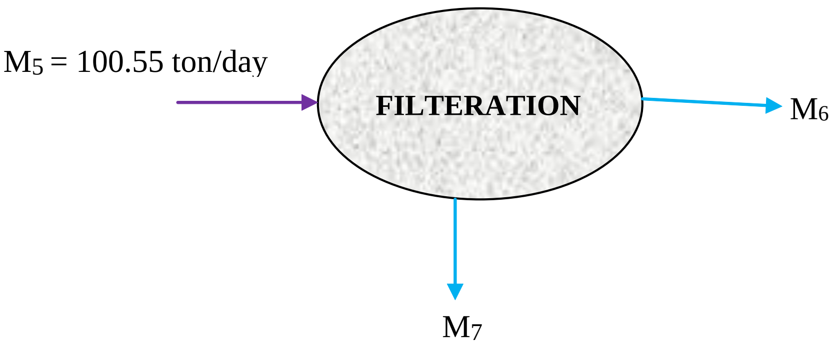
Where M_3 = 4.55 ton of dried banana stem

$M_4 = 96\ m^3$ of cooking liquor

$M_5 = M_4 + M_3 = 96 + 4.55 = 100.55$ ton/day

5.1.4. Filtration

- Filtration is done in order to remove the lignin traces completely and to separate the brown stock from the black liquor (the brown liquor is required for pulp production)



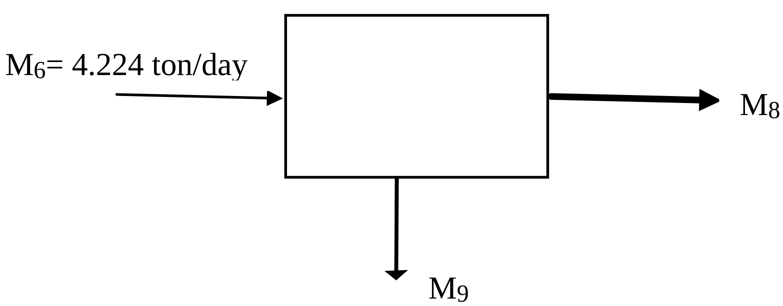
From Table 8 Summary of results in each unit operations

$M_6 = \frac{17.6\ g * 3\ ton/day}{12.5\ g} = 4.224$ ton/day $\qquad M_5 = M_6 + M_7$

$M_7 = M_5 - M_6 = 100.55$ ton/day $- 4.224$ ton/day $= 96.32$ ton of black liquor/day

5.1.5. Washing

Once filtration is finished the brown stock will be washed in order to remove any remaining lignin traces.



From table 8: $M_8 = \frac{17.2\ g * 3\ ton/day}{12.5\ g} = 4.128$ ton/day

$M_6 = M_8 + M_9,\ M_9 = M_6 - M_8 = 4.224$ ton/day - 4.128 ton/day

$M_9 = 0.096$ ton of lignin and some black liquor removed/day.

5.1.6. Bleaching

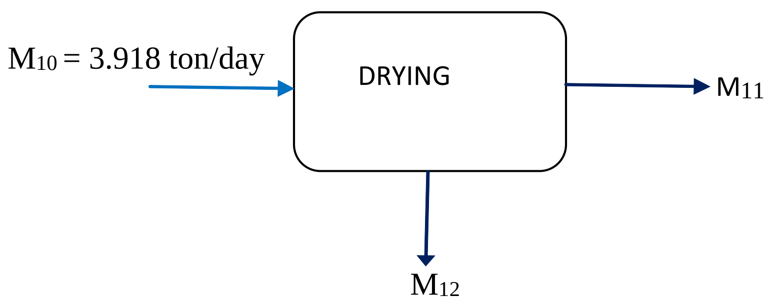
Bleaching decreases the mass of pulp produced by about 5%

4.128 * 5% = 0.21 ton/day

Pulp produced = 4.128 - 0.21= 3.918 ton/day

5.1.7. Drying

Drying is used any water amount existing after bleaching



From table :8, $M_{11} = \frac{\mathbf{12.7\ g * 3\ ton/day}}{\mathbf{12.5\ g}}$ = 3.048 ton/day

$M_{10} = M_{11} + M_{12},\ M_{12} = M_{10} - M_{11}$ = 3.918 ton/day- 3.048 ton/day =0.87 of water removed

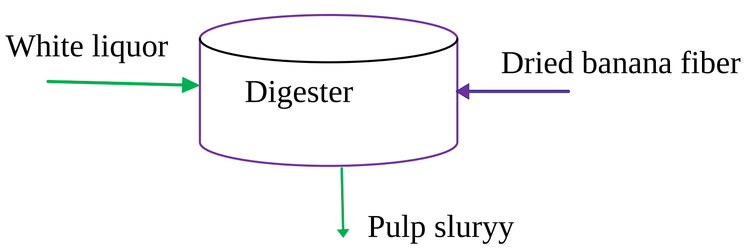
Table 9: material balance summary

Unit operations	Input (ton/day)	Output (ton/day)
Chopping	4.8	4.8
Drying	4.8	4.55
Digesting	4.55 96m3	100.55
Filtration	100.55	4.224 brown stock 96.326 black liquor

Washing	4.224	4.128
Bleaching	4.128	3.918
Drying	3.918	3.048 $0.87m^3$ of water removed

5.2. Energy Balance

Energy Balance on Digester



✓ Assume that the condition is steady state condition that is there is no heat generation, Consumption and accumulation during the process. So that, the amount of energy required to heat the digester would be as follows:

E in + E generation + E consumption = E out + E accumulation

E in = E out

Q = ṁCpT= ṁCp (T-T ref)

T_{in} = Temperature in = 25°C

T_{out} = Temperature out = 90°C

Q = [(ṁ dried banana stem * Cp dried banana stem) + (ṁ white liquor * Cp white liquor)] * T

Cp H_2O = 4.18KJ/Kg K

Cp NaOH = 28.23J/mol K = 0.70575KJ/Kg K

Cp Na_2S = 0.102 + 0.003869 T (K) but the room temperature is 20 or 293.15K

So that; $CpNa_2S$ = [0.102+0.00386]KJ/Kg K = 1.2362KJ/Kg K

- Hence specific heat capacity of white liquor is the average heat capacity of water, sodium Sulphide and sodium hydroxide.

Cp white liquor = CpH_2O + Cp NaOH + $CpNa_2S_3$

= 4.18KJ/Kg K + 0.70575KJ/Kg K + 1.2362KJ/Kg K/3

= 2.04065KJ/Kg K

Cp dbs = Specific heat capacity of the dried banana stem = 0.477 KJ/Kg K

Given that: - reference temperature is at 200C

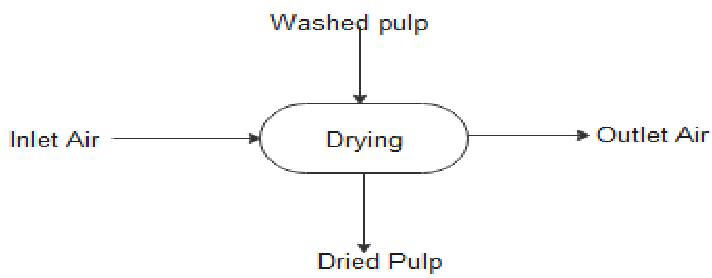
Then the amount of heat required for the digester will be:

Q= [(4.8tons/day * 0.477KJ/Kg K) + (105.55tons/day * 2.04065KJ/Kg K)] * (363.15 -293.15) K = [(4.8tons/day*1000kg/tons*1day/86,400sec*0.477KJ/KgK) + (105.55tonne/day*1000Kg/tons* 1day/86,400sec*2.04065KJ/Kg K)] * 70 K

= (26.5J/sec + 2492.95J/sec) * 70 K

= 176.36KW = 0.17636W

Energy Balance on Drier



- Assume that during drying process there is no heat generation, consumption and Accumulation. So that, the energy balance becomes:

E in + E generation + E consumption = E out + E accumulation

E in = E out

$Q = \dot{m}\ Cp\ T = \dot{m}Cp\ (T\text{-}T_{ref})$

Q = [(ṁ dried banana stem * Cp dried banana stem) + (ṁ white liquor * Cp white liquor)] * Δ T

Moisture content of washed pulp (m.c) = wet solid-dry solid/wet solid= 0.456

Inlet temperature of washed pulp = 200C = 293.15 K and Reference temperature = 0^oC

Moisture content of dried pulp = 10%

Mass flow rate of washed pulp = 4.224 ton/day

Mass flow rate of dry air = 24.52536kg/day = 0.000284Kg/sec

Inlet temperature of air = 150^oC = 373.15 K

Outlet temperature of air = 30^oC = 303.15 K

Specific heat capacity of water = 4.18KJ/Kg K

Specific heat capacity of dry air = 1.005KJ/Kg K

Specific heat capacity of dry pulp = 0.507 KJ/Kg K

- For the wet solid or interring to the dryer, the mass flow rate of water can be calculated as:

ṁ water = MC * ṁ washed pulp

= 0.456* 4.224tons/day * 1000Kg/tons * 1day/86,400sec

= 0.022Kg/sec

- Energy balance on inlet air (hot air stream)

$Q = \dot{m}\ Cp\ \Delta T$

= heat contained by incoming dry hot air + heat contained by water vapor with dry air.

Q= [(ṁ dry air * Cp dry air) + (ṁ water vapor in dry air * Cp water vapor)] *Δ T

- Assume that the mass of water vapor in dry air is negligible. So that, the amount of heat required becomes:

$Q = (\dot{m}\ \text{dry air} * Cp\ \text{dry air}) * \Delta T$

$= 0.000284 Kg/sec * 1.005 KJ/Kg\ K * (423.15-273.15)\ K$

$= 0.0422 KW$

- Energy balance on wet solid (washed pulp)

$Q = \dot{m}\ Cp\ T$

$Q = [(\dot{m}\ \text{water} * Cp\ \text{water}) + (\dot{m}\ \text{dry pulp} * Cp\ \text{dry pulp})] * \Delta T$,but

$\dot{m}\ \text{dry pulp} = (0.049-0.022)\ Kg/sec = 0.027\ Kg/sec$

$= [(0.022 Kg/sec * 4.18 KJ/Kg\ K) + (0.027 Kg/sec * 0.507\ KJ/Kg\ K)] * (293.15-273.15) K$

$= 2.113 KW$

- Amount of heat required for the drying will be:-

$QT = Q\ \text{dry air} + Q\ \text{washed pulp} = 0.0422 KW + 2.113\ KW = 2.155 KW$

CHAPTER SIX

6. COST ANALYSIS AND ECONOMIC EVALUATION

6.1 Purchased Equipment Cost

1. Cost of mixer/agitator: From table 6.2 in the middle of 2004 Coulson and Richardson.

Mixer type is propeller

- Then the purchased equipment cost (C_e) is calculated as; $\mathbf{C_e = C\ S^n}$

Where C_e = purchased equipment cost, ETB

S = characteristic size parameter; in the unit given in table6.2

C = cost constant in $ from table 6.2

n = index for that type of equipment.

- The mixer has 1184.62hp which is greater than the range of our data so, we need to use maximum of our data range**.** Size range 5-75

1hp = 0.7455Kw

1184.62 hp = X ⟹ X= 1184.62hp*0.7455Kw/1hp

X = 883.1342Kw

Cost in 2004

Cost index (C) ----------1900

Index (n) ----------------0.5

Which is out of range due to this reason and need to use maximum range of the data = 75Kw

Then purchased equipment cost (C_e) is calculated as

$C_e = C\ S^n = 1900*75^{0.5}$ = 16,454.483$ purchased cost in 2004G.C.

But the purchased cost in 2018G.C

Cost in 2019 = cost in 2004 * index in 2018/index in 2004

Year cost index

2004--------------------------------108

2005--------------------------------112

2017 ----------------------------- 160**,** by extrapolating index of 2019 = 168

2020-------------------------------X

The cost in 2020 = 16,454.483$*168/112=24,681.724$

Convert to the ETB, 1$ = 46ETB (call centre 951, august 20 2021)

Mixer cost (C_e 2020) = 24,681.724$ *46 ETB = 1,135,359.304 ETB

2. Cost of digester: from table 6.2 in the middle of 2005G.C.

Type = constructed from steel

Size = 36.66m3

Purchased digester cost in 2005=2400$

But, the size range = 1-50 so, it need to use the maximum size from the range

Size index = 2400$

Index = 0.6

Ce = $C*S^n$ = 2400$*$(36.66)^{0.6}$ = 20,831.79$

Purchased digester cost in 2004 20,831.79$. But the purchased cost in 2019 computed as;

The cost from processing engineering is:

Year cost index

2004-------------------108

2005-------------------112 by extrapolating index of 2019 = 168

2020-------------------X

The cost in 2020 = cost in 2005*cost index 2020/cost index 2005

= 20,831.79$*168/112 = 31,247.68$

= 31,247.68$ *46ETB/1$

= 1,437,393.28ETB

3. Cost of diffuser washer:

Size of diffuser washer is 7.55m3 cost = 2400

Size range 1-50 index = 0.6

Purchased equipment cost in 2005G.C

$Ce = C\ S^n$ = 2400$*$(4.11)^{0.6}$

Cost in 2005 = 5,604.23$ and cost in 2020 can be calculated as

Cost in 2020= cost in 2005*cost index 2020/cost index 2004

The cost index from processing Engineering:-

Year cost index

2004----------------108

2013----------------112 by extrapolating cost index in 2018 = 168

2020--------------------X

Cost in 2020 = 5,604.23$*168/112 =8106.12$

= 8106.12$*46ETB/1$ = 372,881.52ETB

4. Cost of screen conveyor dryer:

- The area of the screen conveyor dryer is 0.37m^2 or 4 ft^2.

From the Appendix 1, Equipment Cost Estimates, the cost in 1988 G.C. can be determined by extrapolating

Area (ft^2)	Purchased Cost ($)*1000
5,000	160
6,000	170

By extrapolating the cost in 1988= 110,431$

4 ft^2 -------------------------------------x

To an early of 1989, to a Chemical Engineering, the index number is 320. Neglecting the negative sign of index for ease of calculation and extrapolation.

Year	Index
1989	320
2005	112
2020	y ⟹ y= 71.53

The cost in 20120 becomes Cost in 2020= cost in 1988*Cost index in 2020/cost index in 1988

= (110,431$*71.53/320)*46ETB/$ = 1,135,499.856 ETB

5. Cost of water storage tank: from table 6.2 in the middle of 2005G.C Coulson and Richardson. Storage tank floating roof.

Size =13.3m^3 Cost = 4350$

Size range = 50-8000 Index = 0.55

- Purchased equipment cost of water tank in 2005G.C is

Ce = C Sn = 4350$*(13.3)0.55 = 18,055.422$

The purchased cost of water storage tank in 2020 is

Cost in 2020 = cost in 2005*cost index 2020/cost index 2005

=18,055.422$*168/112 = 27,083.133$ *46ETB/$ =1,245,824.118ETB

6. **Cost of surplus tank: -** surplus tank is a vertical process tank constructed from carbon steel at m3 capacity with a size range of 50-800m3.

- Purchased equipment cost is calculated as: - $Ce = C\ S^n$

Cost in 2005→4350$

Size index→0.55

C2005= 4350 * $(16)^{0.55}$= 19,987.35$

Cost in 2020= cost in 2005*index in 2020/index in 2005

Year cost index

2004--------------108

2005--------------112 by extrapolating cost index of 2020= 168

2020--------------X

Cost in 2020 = 19,987.35$* 168/112 = 29,981.025$

Surplus tank cost =29,981.025$*46ETB/1$ =1,379,127.15ETB

7. Cost of dearator:-the dearator is shell and tube type equipment in order to prevent corrosion water is in the shell side. The heat transfer area of a dearator is 10.65m^2 (114.754ft^2) from table 6.2 Coulson and Richardson in the middle of 2004 the purchased equipment cost for this heat transfer area will be obtained by interpolation method.

Area (m^2) purchased cost ($)

10.65-----------X by interpolating cost in 2003= 15,650$

50-----------55,000

60---------65,000

Cost in 2020= Cost in 2003*cost index in 2020/cost index in 2003. From Coulson and Richardson process engineering figure the index in 2003 is 106 and in 2020 it is 157 (found by extrapolate) Then Cost in 2021 = 15,650$* 157/106 =23,179.72$

= 23,179.72$*46ETB/1$

= 1,066,267.12ETB

8. Cost of boiler: - the capacity of electrical boiler is 2520kg/hr (5563lb/hr.)From Kostnads data process untrusting in 2003 the purchased equipment cost for this heat transfer area will be obtained by extrapolation method.

Capacity (lb/hr) purchased cost ($)

5000-----------200,000

556------------------X By extrapolating cost in 2003= 8,890.75$

1000------------10,000

Cost in 2020= Cost in 2003*cost index in 2020/cost index in 2003. From Coulson and Richardson process engineering figure the index in 2003 is 106 and in 2020 it is 157(found by extrapolate) Then

Cost in 2021=8,890.75$* 157/106 =18,758.759$ = 18,758.759$*46ETB/1$

=862,902,914ETB

- The total purchased equipment cost for the main unit operations will be the sum of the purchased equipment cost of each unit operation.

Total purchased equipment cost is:

1,135,359.304ETB+1,437,393.28ETB+372,881.52ETB+1,135,499.856 ETB+1,245,824.118ETB+1,379,127.15ETB+1,066,267.12ETB+862,902,914ETB

=8,635,255.255 ETB

Cost of pump: the type of pump is centrifugal pump; because of it is not viscous, low pressure drop and low flow velocity

Pump-1: for the mixer to be pump or drive the water with a capacity of 19.36gpm.

- The pump purchased cost from Kostnads data process utrustning in 2003 is;

Capacity (gpm) purchased cost ($)

10----------------------------3000

19.6---------------------------X By interpolating the cost in 2003 = 3,106.67$

100--------------------------4000

The cost in 2020 becomes Cost in 2020 = cost in 2003*cost index2020/cost index 2003.

=3,106.67$*157/106 = 4,601.38$*46ETB/$

=211,663.48ETB

Pump-2: for the white liquor with a capacity of 2.44gpm.

- The pump purchased cost from Kostnads data process utrustning in 2003 is

Capacity (gpm) purchased cost ($)

2.44------------------------X by interpolating the cost in 2003 = 2,915.3$

10---------------------------3000

100----..-------------------4000.

From Coulson and Richardson, process engineering figure, the index in 2003 is 106 and in 2020 it is 157 (found by interpolating)

Cost in 2020 = cost in 2003*cost index 2020/cost index 2003

= 2,915.3$*157/106 = 4,317.94$ *46ETB/$ =198,625.24ETB

Pump-3: to drive the water to the washer with a capacity of 18.4gpm.

- The pump purchased cost from Kostnads data process utrustning in 2003 is;

Capacity (gpm) purchased cost ($)

10-------------------------------------3000

52.43-----------------------------------X by interpolating the cost in 2003 = 3,471.44$

100---------------------------------------4000

The cost in 2019 becomes Cost in 2020 = cost in 2003*cost index 2020/cost index 2003

= 3,471.44$*157/106 = 5,141.66$*46ETB/$ =236,516.36ETB

Pump-4: to drive the digested wood chips with a capacity of 74.1gpm.

- The pump purchased cost from Kostnads data process utrustning in 2003 is;

Capacity (gpm) purchased cost ($)

10----------------------------3000

74.1--------------------------X by interpolating the cost in 2003 = 4,287.77$

100---------------------------4000

Cost in 2020 = cost in 2003*cost index 2020/cost index 2003

= 4,287.77$*157/106 = 6,350.75$*46ETB/$ =292,134.5ETB

Pump-5: to drive the pulp to the washer with a capacity of 11.655gpm.

- The pump purchased cost from Kostnads data process utrustning in 2003 is;

Capacity (gpm) purchased cost ($)

10------------------------------------3000

11.655------------------------------X by interpolating the cost in 2003 = 3,018.39$

100--------------------------------400

Cost in 2020= cost in 2003*cost index 2020/cost index 2003

= 3,018.39$*157/106 = 4,470.63$*46/$ =205,648.98ETB

Pump-6: - from dearator to boiler which has the same capacity with the second pump so that cost in 2020 becomes 198,625.24ETB .

Therefore, the total purchased cost for centrifugal pump is the sum of each pump.

So that;

211,663.48 ETB +198,625.24 ETB +236,516.36 ETB + 292,134.5 ETB+205,648.98ETB + 198,625.24ETB

=1,343,213.74ETB

Cost of belt conveyor

Cost of belt conveyor to digester:

The length of a belt conveyor is 1.77m and the width of a belt conveyor is 0.67m. From table of 6.2, Coulson and Richardson, vol.6

Size = 1.77m, Size range = 2-40,Cost in $ = 2900

Index= 0.75 but the size is out the range so we take the lower range that is 2m. The purchased cost of a belt conveyor that transported to the digester process in mid-2005 G.C.

C_e= C S^n= 2900$*$2^{0.75}$ =4,877.199 $ .The cost in 2020 becomes

Cost in 2020= Cost in 2005*Cost index in 2020/Cost index in 2005

=4,877.199 $*168/112 =7,315.79 $*46 ETB/$

=336,526.34ETB

Cost of belt conveyor from the washer to dryer

- The width of a belt conveyor is 0.75m and approximate to 1m wide. From the table 6.2. Coulson and Richardson, vol.6

Size =1.075m Cost = 2900$

Size range = 2-40 Index = 0.75

But the size is out of the range so we take the lower range that is 2m

- Purchased equipment cost of water tank in 2005G.C is

Ce = CS^n = 2900$*$(2)^{0.75}$ = 4,877.199$

- The purchased cost of belt conveyor in 2020 is

Cost in 2020 = cost in 2020*cost index 2020/cost index 2005

=4,877.199$ *168/112 = 7,315.79 $*46 ETB/$

=336,526.34ETB

Cost of belt conveyor from the dryer to store house:

- The width of a belt conveyor is 0.67m and approximate to 1m wide. From the table 6.2 Coulson and Richardson, vol.6.

Size =2m Cost = 2900$

Size range = 2-40 Index = 0.75

- Purchased equipment cost of a belt conveyor in mid 2005G.C is

$Ce = CS^n = 2900\$*(2)^{0.75} = 4,877.2\$$

- The purchased cost of belt conveyor in 2020 is

Cost in 2020 = cost in 2005*cost index 2020/cost index 2005

= 4,877.2$*168/112 = 7,315.79$*46ETB/$=336,526.8ETB

- Therefore, the total purchased cost of belt conveyor needs one reservoir conveyor so that

= [336,526.8ETB +336,526.34ETB +336,526.34ETB] = 1,009,579.02ETB

Total purchased equipment cost= (8,635,255.255 +1,343,213.74+1,009,579.02)ETB

= 10,988,048.02ETB

Table 10: Purchased cost of each equipment

Equipment	Number of equipment	Purchased cost(ETB)
Water storage tank	1	1,245,824.118
Mixer	1	1,135,359.304
Digester	1	1,437,393.28
Diffuser	1	372,881.52

Dryer	1	1,176,130.07
Surplus Tank	1	1,379,127.15
Deaerator	1	1,066,267.12
Boiler	1	862,902.914
Belt Conveyor	3	1,009,579.02
Pump	6	1,343,213.74
Paper Molding Machine	1	808,191.86
Packaging	1	935,216.12
Storage	1	1,266,744.15
Total		13,998,200.15

6.2 Estimation of total capital investment

Ratio factors for estimating capital investment items based on delivered equipment cost (pulp and Paper production is from solid processing plant)

Direct cost

Table 11: Total direct cost

No	Item	Percentage (%)	Cost in ETB
1	Purchased equipment cost	100PEC	13,998,200.15
2	Installation cost	45 PEC	6,299,190.07
3	Instrumentation and control cost	9 PEC	1,259,838.01
4	Piping	16 PEC	2,239,712.02
5	Electrical (installed)	10 PEC	1,399,820.02

6	Building(including service)	25 PEC	3,499,550.04
7	Yard	13 PEC	1,819,766.02
8	Service facility	40 PEC	5,599,280.06
9	Land	16 PEC	2,239,712.02
	Total Direct Cost		56,955,248.4

Indirect cost: expense which are not directly involved with material and labour of actual installation of complete facility.

Table 12:Total indirect cost

No	Item	Percentage (%)	Cost in ETB
1	Engineering and supervision	33PEC	4,619,406.05
2	construction expense	39PEC	5,459,298.06
	Indirect Cost		10,078,704.11
3	Contractor fee	17PEC	2,379,694.03
4	Contingency	39PEC	5,459,298.05
	Total		18,217,786.19

Fixed cost is the sum of the total direct and indirect cost. That is,

FCI = DC+IC+ Contractor fee+ Contingency

= (56,955,248.4+18,217,786.19) ETB = 75,173,034.59ETB

Total capital investment is the sum of the fixed capital investment and working capital investment.

That is;

TCI= FCI +WC…………………..equation (1)

But, working capital is 15% of the total capital investment. That is;

WC = 15%TCI

WC = 0.15TCI………equation (2) Substituting into equation (1)

TCI =FCI +0.15TCI

TCI-0.15TCI = FCI

TCI= FCI/0.85 = 75,173,034.59ETB/0.85 = 63,897,079.4ETB

Then, working capital is; WC =0.15TCI = 0.15 * 63,897,079.4 ETB

WC = 9,584,561.9ETB

6.3. Estimation of total product cost

- Total Production Cost = Manufacturing Cost + General Expense

1. Manufacturing Cost

1.1 Fixed Charges (FC)

a) Depreciation: is 10% of fixed capital investment for machinery and equipment's

    i. DP = 10%FCI = 0.1* 54,173,034.59ETB =5,417,303.46 ETB

b) Local tax: (1-4% fixed capital investment)

c) =1% FCI =0.01*31,639,839.25ETB=316,398.39ETB

d) Insurance: (0.4-1% of fixed capital investment)

    e) = 0.4% FCI = 0.004*31,639,839.25ETB =126,559.357 ETB

f) Rent (8-12% of value rented land and buildings – for the safe of promoting local investors, in Ethiopia provide land free from taxes and rents.

Therefore, the fixed charges are the sum of the depreciation, local tax, insurance and rent.

Fixed charge =Depreciation +Local tax + Insurance

= (3,163,983.92+316,398.39+126,559.357) ETB= 3,606,941.667ETB

Therefore, the total product cost can be calculated from fixed charges

Fixed Charges = 10-20% of total Product Cost

In order to easy my calculation find total product cost depending with relating fixed charges. We take (20%)

Fixed Cost = 20%*TPC= 0.2*TPC

TPC = FC/0.2 =3,606,941.667 ETB /0.2 = 18,034,708.34ETB (this is theoretical total product cost)

a. **Direct production costs (about 60% of total product cost**)

i. Raw material cost (RMC) (10-50% of Total Product Cost)

=10% of Total Product Cost=0.1*18,034,708.34ETB =1,803,470.84ETB

ii. Operating labour cost (OPC) (10-20% of total Product cost) =10%TPC

=0.1*18,034,708.34ETB =1,803,470.84ETB

iii. Utilities (UC) (10-20% of Total Product Cost) = 10% of Total Product Cost

= 0.1*18,034,708.34ETB =1,803,470.84ETB

iv. Maintenance and Repairs (MRC) (2-10% FCI)

=2% FCI= 0.02*18,034,708.34ETB = 360,694.16ETB

v. Operating supplies (0.5-1%) FCI =0.005* FCI =0.005*18,034,708.34ETB=90,137.54ETB

vi. Laboratory charges (1-2% of TPC) = 0.01*TPC=180,347.08ETB

vii. Patents and royalties (0-6% of total product cost) = 0.01*18,034,708.34ETB =180,347.08ETB

Direct production cost (DPC) = RMC +OPC +UC+MRC+OPC+LCC+P&R
=(1,803,470.84+1,803,470.84 +1,803,470.84+m360,694.1+90,137.54
+180,347.08+180,347.08)ETB = 6,221,938.22ETB

b. Plant Over Head Cost (50-70% of cost for operating labor, supervision and maintenance or 5-15% of total product cost)

= 6% Total Prouct Cost = 0.06*18,034,708.34ETB = 1,082,082.5ETB

Therefore, the manufacturing cost is the sum of the direct production cost (DPC), fixed charge (FC) and Plant Overhead Cost (POHC).

MC = DPC +FC +POHC

= (6,221,938.22ETB +3,606,941.667ETB +1,082,082.5ETB) = 10,910,962.39ETB

2. General Expenses

2.1 Administrative costs (Supervision and maintenance 2-6% of total product cost) = 2% of Total Product Cost = 0.02*18,034,708.34ETB =360,694.16 ETB

2.2 Distribution and selling costs (2-20% of Total Product Cost)

= 3% of Total Product Cost = 0.03*18,034,708.34ETB= 541,041.25ETB

2.3 Research and development cost (about 5% of Total Product Cost)

=5% of Total Product Cost =0.05*18,034,708.34 = 901,735.41 ETB

Therefore, the general expense is the sum of the administrative cost, distribution and selling cost and research and development cost.

GE=AC + D&SC + R&DC = (360,694.16+541,041.25+901,735.41) ETB =1,803, 470.82ETB

Total Production Cost is the sum of the manufacturing cost and general expense.

TPC = MC+GE = (10,910,962.39+1,803, 470.82) ETB = 12,714,433.21ETB.

Table 13: Total capital investment and total product cost.

Parameters	Estimated cost (ETB)
Direct Cost	24,074,849.95
Indirect Cost	7,564,989.3
Contractor fee (about 5% of direct and indirect plant costs)	1,045,567.62
Contingency (about 10% of direct and indirect plant costs)	2,091,135.3
Fixed Capital Investment (FCI=DC+IC)	31,639,838.25
Working Capital	5,583,501.04
Total Capital Investment(FC+WC)	37,223,340.29
Direct Product Cost	6,221,938.22
Plant Over Head Cost	1,082,082.5
Manufacturing Cost(DPC+FC+POHC)	10,910,962.39
General Expense (GE)	1,803, 470.82
Total Production Cost(MC+GE)	12,714,433.21

6.4. Economic Analysis

A. Profitability analysis

Gross earning cost is calculated as;

GEC = Total Income - Total Production Cost

=annual sale revenue –Total production cost,

But, Total Income (sale revenue) = capacity * selling price, but the working day per year is 320day)

Mass of one wrapping paper = 20g, 1tone =1000kg,

Selling price of one wrapping paper=2ETB, 1package=12 pieces (240g) = 24ETB

= 3ton/day * 320 day/year * 100,000ETB/ton = 96,000,000ETB/year

By taking a base of 1 year, the total income become

Total Income = 96,000,000 ETB

Gross earning cost (GEC) = (96,000,000 –12,714,433.21) ETB

= 83,285,567ETB

The Net gross earning (Net profit) cost can be calculated as;

NGEC = GEC * (1-Income tax). In most area of Ethiopia the income tax is taken as 35% to the official government. Then,

NGEC = GEC (1-0.35) =GEC*65% = 83,285,567ETB *0.65

=54,135,618.55ETB

Based on the projected profit and loss statement, the project will generate a profit throughout its operation life. The annual net profit after taxes is 116,535,618.4 ETB per year during the life of the project.

B. Payback period calculation

We calculate the payback period in order to know the project is feasible or not feasible.The payback period of the project will be;

Payback period= $\frac{\text{Fixed capital investment}}{\text{Net cash annual}}$

Net cash annual= Net gross earning + Depreciation=54,135,618.55 + 5,417,303.46 ETB

=59,552,922.01ETB/year

Payback period= $\frac{75{,}173{,}034.59 \text{ ETB}}{59{,}552{,}922.01 \text{ ETB/year}}$ = 1.92year

1.92 year means 1year+9month+2days.

Therefore, the payback period of the project is less than the payback period of reference (i.e. 1.92<5),

C. Rate on return (ROR) rate of return calculation

ROR = Net Gross Earning Cost/Total Capital Investment*100%

= 54,135,618.55ETB / 63,897,079.4 * 100%

= 54.3%

The plant returns 54.3**%** of the capital investment per year.

CHAPTER SEVEN

7. PLANT LOCATION AND ENVIRONMENTAL CONCERNS

7.1 plant location

The plant location is decided to be in Arba Minch based on the major factors that can have an impact on the whole process as well as on the profitability of the plant. Some of these factors include;

Raw material

Since Arba-Minch is one of the first largest producers of banana in the country hence there is Easily availability of raw material (banana tree waste) It is estimated that banana from Arba Minch has more than 80% of the market share in Ethiopia and 40% of the market share in Addis Ababa. Consumers in Addis Ababa, Hawassa, Adama, Shashemene, Bahir Dar and other major towns prefer bananas from ArbaMinch for its good taste. ArbaMinch is also an important source of banana suckers for many other parts of the country.

Energy Availability

Even though energy scarcity is a main problem in Ethiopia, As long as the plant is city centered it has a good opportunity of energy sources specially electricity comparing to other factories in rural areas.

Water Supply

Arba-Minch is a home for one of the largest and many lakes of the country. Beside this region is rich in ground water sources. The rift valley created lake and the high amount of ground water makes the region amongst fresh water towers of the whole country. So, we can conclude that water supply is not also an issue in terms of shortage. Labor Likewise other regions there is high unemployment rate of youths in the southern part of Ethiopia which is around 119,176 people (40,404 males and 78,171) and 574,806 economically not active people (236,660 males and 338,146) according to central statistics agency of the country.

Market

Even though large number of consumers are located in Adiss Ababa due to expansion of industrialization and education the southern region of the country contains many users which will allow the plant to control these region sales.

Climate

Since Arba-Minch is comparatively on a low elevation (1285m) above sea level, high wind wave is not a problem and doesn't cause a natural trauma (disaster). And the air humidity is also low which can't cause corrosion on metallic equipment's.

7.2 Plant Layout

Plant layout is a plan of optimum arrangement of facilities including personnel, operating equipment, storage spaces material handling equipment and all other supporting services among with the density of best structures to contain all these facilities.

The overall objectives of plant layout is consists of organizing the whole facilities and working areas with most efficient way and at the same time satisfactory and safe for the personnel doing with brain relaxing site.

Figure 21: plant layout

7.3. Environmental Impacts

The major negative environmental impacts of the project include the black liquor from Digestion process, unless it is treated (recover chemicals for reuse in the pulping process).During the manufacturing activities of the pulp there is also a generation of wastewater. This will have an adverse effect on the environment.

The principal air emissions in pulp production consist of process gases which vary by type of pulping process and which may include sulphur compounds (with associated odour issues), particulate matter, volatile organic compounds, chlorine, carbon dioxide, and methane. The Positive impact of the project is since our raw material is banana tree waste, in banana plantations, after the fruits are harvested, the trunks or stems will be wasted. Billion tons of stem and leave wastes are thrown away annually. Banana trees fruit once in their live. After 47 harvesting, the banana stem is considered as a waste material. Improper disposal can pose a problem for the environment.

The waste causes emission of toxic gases including CO2 and also gives growth to the harmful fungi which attacked remaining banana trees. Therefore, it makes sense to turn such waste into a useful product like pulp by using the concept “from waste to wealth”.

CHAPTER EIGHT

8. CONCLUSION AND RECOMMENDATION

8.1. Conclusion

From this project, it can be concluded that banana fiber is a potential raw material for making pulp. And done the kraft processes (i.e. not compare with soda process).

In General from this project we conclude that Banana stem which is currently wasted after harvesting fruits is good cellulosic source and is a good raw material for Pulp and paper making industry. This waste is also causes environmental pollution. Thus the utilization of waste banana stem helps us to save our forest and decrease environmental issues and also it grows and widely available in most part of Ethiopia.The pulp obtained in the process was less dark in colour process. The pulp obtained after bleaching was observed and found that pulp was whiter in colour to before bleaching, as bleaching agent required breaking the traces of lignin was more in the process. The kraft process has the yield of 0.58 and the moisture content is 60.8% with the consistency of 39.2%. Because of this reason we can find the traces lignin was more in the process. The optimum production of pulp was 72.25% at 13.5% white liquor concentration for the cooking time of 4:30 hours, and also the maximum mass of pulp was 72.25% at the cooking time of 4:30 minutes with 13.5% white liquor concentration and the minimum mass was obtained 52.5% at minimum concentration (12.5%) and minimum time (5 hour). From those results, to determine material balance and energy balance the optimum pulp production process is more efficient than that of the other conditions.Production of pulp and paper is feasible from the economic point of view in that its internal rate of return is 54.3% mean that the factory recover its cost by 54.3% in a year. Moreover, the payback time is less than three years.

8.2. Recommendation

- During this project we have faced a lot of challenges that affects our laboratory results like there was insufficient laboratory equipment (like Chopper, Chemical, filter, Visco meter...etc), Chemical (like sodium sulfide,).
- Method of chemical pulping used for this study was Kraft or sulphate pulping process which provides a bleachable grade pulp with banana fiber yield 72.5%. But before doing any further study on it, investigation of another method of chemical pulping such as soda method is advisable if it results better pulp yield.
- With increasing concern over global warming and effect of acid rain using wood as raw material for the manufacturing of pulp and paper production causes deforestation so using non wood materials like banana tree waste is a good choice in terms of decreasing deforestation.
- The black liquor from the digestion process causes environmental problems so by recovering Chemicals like NaOH from the process we can decrease the environmental impacts.
- This project can be an initial idea to do further detailed researches. So by applying the project on ground and establishing pulp producing factories in our country. We can Save foreign currency and create Job opportunities.
- The use of renewable agricultural by products for pulp production as non-wood cellulosic fibers would be great advantage for countries with limited wood forests, and would increase the profit of farmers in developing countries.

REFERENCE

Akhouri, S., & Kumar, S. (2015). Caustic Soda Delignification of Khar Grass for Separation of Cellulosic Fibers. International Conference on Advances in Environment Research Volume 87 of IPCBEE.

Anon. (1987). TAPPI test methods 1988.

A.smook. Gary. (1992). Handbook for pulp and paper technologists. Vancouver, Bellingham. : s.n., Vol. 1.

Baldwin C. (2016).How to Make Banana Paper [online].Available from: http://www.ehow.com/how_6464815_make-banana- paper. html [Accessed 26th January 2016].

Bandyopadhyay, L. a. (2013). International Journal of scientific and Engineering Research.

Caulfield, D. F., & Gunderson., D. E. (1988). Paper Testing and Strength Characteristics. paper preservation symposium (pp. 31-40).

Chaudhury J., Singh D.P., Hazra S.K., Sunnhemp (Crotalaria juncea, L). from http://www.assamagribusiness.nic.in/sunnhemp.pdf. . 07, 23, 2013.

C. Ververis ,K.G. (2006). Cellulose, hemicelluloses, lignin and ash content of some organic.

ECCIDI. (2016). Ethiopian Chemical and Construction Input Development Institute .

Edward, F.T. (1982). Paper and Papermaking. Lexocon : New Age Encyclopedia,

Ekhuemelo, D. O., Oluwalana, S. A., & Adetogun, A. C. (2006). Potentials of Agricultural Waste and Grasses in pulp and Papermaking. Journal of reaserch in forestry, wildlife and environment.

FAO UN. (2015). Global Forest Products Facts and Figures. Forest Products Stastcs,

Garber M. (2012). A Brief History of Wrapping Paper. Wrappers' Delight.

Hayes M. ca. (2000). Agricultural Residues: A Promising Alternative to Virgin Wood Fiber. Resource Conservation Alliance.

Hussain I. and Tarar O. M. (2014). Pulp and Paper Making by using Waste Banana Stem. Journal of Modern Science and Technology [online] Vol. 2. No. 2.

Jaya Bharat Reddy Marella. (2014). International Journal of Engineering Research and General science.

J.M Coulson and J.F Richardson. (2005). ‘’Chemical Engineering Vol 1,2,6 fourth Edition press, NewYork

Jokioinen, F. A. (1987). paper making process background, non-wood plants as raw material for pulp. MTTagri-foodresearch Finland, plant production research.

Lorentzen , & Wettre. (2016). Pulp Tester Optical Properties.

Maria, G. (April 2007). The Significance of Liquor-to-Wood Ratio on the Reaction Kinetics of Spruce Sulphate Pulpin. Master thesis.

Muraleedharan H. and Perumal K. (2010). Eco-Friendly Handmade Paper Making, p.11

Peters,M.S amd K.D Timber Haus, **(1991)** ‘’Plant Design and Economics for Chemical Engineers’’4th,Edition Mc Graw Hill International Book Company

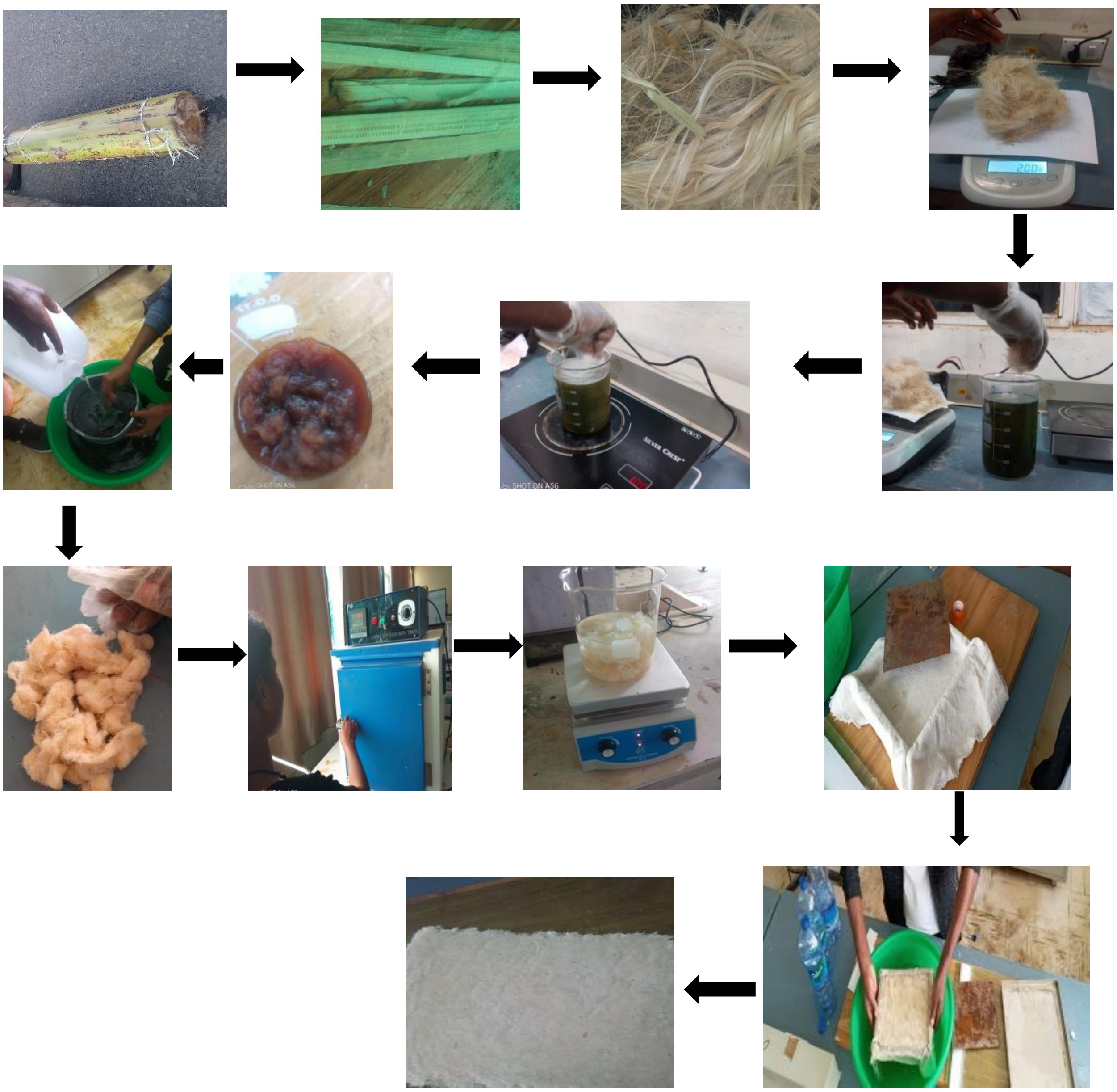
Song, W., Deng, Y., & Zhu, H. (2016). Research on banana fiber Pulping with Ionic Liquid.

Wiley-Vch Verlag Gmb hand Co.KGaA, Weinheim. (2006). Hand book of pulp.

W. Song, Y. Deng, and H. Zhu . (2016). Banana fiber Pulping with Ionic Liquid 1- Ethyl-3-Methylimidazole Bromide. Kem. Ind. 65 (11-12), 579−585.

APPENDIX

Appendix A: Supporting pictures during the study



Appendix B:Calculation

Moisture content of raw material determination

Moisture content = $\frac{W1-W2}{W1} * 100\%$ …………….

$= \frac{20\text{ g}-14.5\text{ g}}{20\text{ g}} * 100\%$ = 27.5%

Yield = $\frac{\textit{wt of pulp produced}}{\textit{wt of original banana stem}} * 100\% = \frac{11.6\ g}{20\ g} * 100\% = 58\%$

Moisture content (M.C) = $\frac{x1-x2}{x1} * 100\%$

Where X_1 = Amount of product obtained before drying (wt. of pulp + water = 29.6g)

X_2 = Amount of product obtained after drying it in air (wt. of dried pulp= 11.6g)

M.C = $\frac{x1-x2}{x1} * 100\%$ = $\frac{(29.6-11.6)}{29.6}$*100% = 60.8%

Consistency = $\frac{\textit{wt of pulp produced}}{\textit{wt of pulp+water}} = \frac{11.6g}{29.6g} * \mathbf{100 = 39.2}\%$