WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

Production of pulp from pineapple wastes/leaves

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DECLARATION

This thesis declares that the work, which is being presented in this document, is for the completion of lab work under the supervision of Dr. Gebre E who is head in chemical engineering program in wolkite University and advise of laboratory assistance in chemical engineering lab. All relevant resources of information used in the preparation of this paper have been duly acknowledged. In such a way that highly declare our original work and preparation of the report with the aid of all resources and materials required for this thesis, has been considerably acknowledged.

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ABSTRACT

Wood contributes majorly as raw material in conventional pulp and paper production worldwide, whereas the depleting forest resources to obtain wood had made a significant impact on the environment and human. This has made the search for alternative fiber in non-wood materials imperative in pulp and paper production. Ethiopia has abundance of agro waste materials like pineapple leaves that have not been fully utilized. Therefore, this study aims at investigating the suitability of pineapple wastes (leaves) in pulp and papermaking. The chemical composition of pineapple leaves are lignin content (11.5%), cellulose content (65%) and ash content(1.2%). The factors which affect the production of pulp were cooking time, temperature and concentration of NaOH and Na_2S. Pulping of pineapple leaf was achieved through chemical pulping method (Soda and Kraft pulping) and the pulp obtained were tested from pineapple waste (leaf) of the pulp yield was (30%, 41.6%) for soda and Kraft pulping respectively. The overall results showed that pineapple wastes have a promising potential as alternatives fibers for pulp making industry.

LIST OF ACRONYMS AND ABBREVIATION

MC	Manufacturing cost
PEC	Purchased equipment cost
FCI	Fixed capital investment
Q	Amount of heat required
TDC	Total direct cost
WC	Working capital
FC	Fixed cost
DPC	Direct production cost
GEC	Gross earning cost
NGEC	Net gross earning cost
BEV	Breakeven point
CF	Cash flow
FCI	Fixed Capital Investment
TCI	Total Capital Investment
PI	Profitability index
ROR	Rate of return
DP	Depreciation
PBP	Payback Period
ASTM	American Society for Testing and Materials

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CHAPTER ONE

1. INTRODUCTION

1.1. Background

The demand and use of pulp and paper have marked the levels of civilization and development of many societies. As a result many developed nations use plenty of pulp and paper. The demand for pulp and paper fiber resources is largely determined by the society's dependence on paper, paper boards and other related products for human welfare. Paper in society is used in education, information storage, advertising, communication, in protection, transportation and security of goods in transit; protection of human health and sanitation in form of tissues and sanitary paper products. Paper making process for long has mainly used wood from tree stems that are cut, debarked, chipped and pulped. It is interesting to note that some environment advocates have proposed the use of non-wood fibers in paper making as a way to preserve natural forests. Both wood and non-wood resources are currently exploited for the manufacturing of pulp, paper and soft boards (]. L. Read, 1995). However, still the major source of pulp which meets more than 80% demand is still wood from forests. However scientists all over the world in the last two decade have been involved in intensive research for the alternative sources of pulp for paper industry (Kamoga Omar Lwako M., Byaruhanga Joseph K., and Kirabira John Baptist ;, 2013).

As environment related climatic changes have become national and international challenges, possible sources of vital human needs, paper inclusive must be looked for from alternative extraordinary sources that offer less adverse impact on the environment. In most cases the non-wood materials such as agricultural food crop residues, grasses and tree leaves which do not have immediate beneficial applications in many communities have been proposed to be potential sources of pulp. Since all these plant materials contain cellulose in form of fibers, they stand to be potential sources for pulp manufacture with less environmental degradation threat (Read, 1995). Besides, the narrow issue of raw material availability, there are other driving forces behind the growing interest in non-wood pulping. In Europe, the overproduction of food and the large subsidies delivered to the agriculture sector have resulted in a need to find alternative uses for grain fields. Non-wood fibers provided the bulk of raw material supplies for paper makers over many centuries, and they still play an important role.

Environmentalists claim that non-wood papermaking is more sustainable and environmentally friendly than wood-based paper production. It is an undeniable fact that both Europe and America share a large, untapped papermaking fiber resource. It should also be kept in mind that fibers harvested annually have a high biomass production potential. Some non-wood plants even give more pulp per hectare than wood. From a marketing perspective, the environmental perceptions related with papers containing non-wood pulp are very positive (McClosekey, 1995). Globally, non-wood pulp production is based primarily on straw (46%), bagasse (14%) and bamboo (6%). Agricultural by-products account for 73% of the world's non-wood pulp capacity, while natural plants such as reed and bamboo account for 18% and the remainder consists mainly of industrial crops (Paavilainen, 1998). In the future, the main non-wood fiber sources will be agricultural by-products such as straw, bagasse and pineapple leaf, or naturally growing plants like reed. No significant increase can be foreseen in the production of pineapple leaf pulp because of people cannot understand the use pineapple waste.

Ethiopia is rich in non-wood fiber materials. Almost all categories of non-wood fiber are found in the country. Several agricultural food crop residues including rice husk, corn straw, okra stalks, corn stalk, plantain stalk, pineapple leaf and corn husks which do not have immediate beneficial applications in many communities have been proposed to be potential sources of pulp (A. T. Rymsza 2007). It has also abundance of agro waste material that have not been fully utilized to maximum production. Examples of such agro waste materials are pineapple leaf. Pineapple (Ananas comosus) is the common tropical plant which consists of coalesced berries. It consists of cellulose, holocelluloses, hemicelluloses and lignin along with some extractives such as gum and resin. Previous researches indicate that pineapple leaf from different cultivar contained higher cellulose content than wood fibre. Such findings suggest that non-wood species can provide agood solution to the need for alternative fibre. Thus the use of pineapple leaf for pulp production is investigated in this study.

1.2. Statement of the problem

Wood contributes majorly as raw material in conventional pulp and paper production in worldwide, whereas the depleting forest resources to obtain wood had made a significant impact on the environment and human. It also contains high lignin content and it needs more chemicals and cooking time to remove the lignin compared to non-woods for pulp production. This has made the search for alternative fibre in non-wood materials imperative in pulp and paper production. Since pineapple plant determines the fiber properties of its constituent; and this paper focuses on production of pulp from pineapple waste. Pineapple waste cause emissions of poisonous substances, unpleasant odor and also gives growth to the harmful fungi when stored in the environment after using. Another problem is that Pulp is not produced in our country so far from paper industry. It is imported and there is scarcity of pulp and paper in our country since the demand increases from day to day life.

1.3. Objectives

1.3.1. General objective

The general objective of this thesis was pulp production from pineapple waste/leaves.

1.3.2. Specific objectives

- To determine cellulose, ash and lignin content of the pineapple wastes.
- To evaluate the parameters affecting production of pulp (Temperature, cooking time and composition).
- To produce pulp using kraft and soda methods in laboratory scale
- To do Engineering analysis(Material balance, Energy balance & economic feasibility)

1.4. Significance of the project

The use of agricultural wastes in pulping and paper-based industries might be advantageous because it prevents the need for disposal. Currently increases farming costs and causes environmental deterioration through firing agricultural residual. It encourages the application of green technology in terms of generating new pulp production from non-wood resources to create more environmentally friendly processes. The use of renewable agricultural byproducts 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 of their income. The study will also help the farmers by providing them an opportunity to generate additional income through extracting or selling the pineapple fruit. In addition, producing pulp from pineapple waste helps in saving foreign currency since the pulp is imported.

CHAPTER TWO

2. LITRETURE REVIEW

2.1. Review on pulp production

Pulp is a fibrous material resulting from complex manufacturing processes that involve the chemical and/or mechanical treatment of various types of plant material. Pulp is one of the most abundant raw materials worldwide which are used predominantly as a major component in the manufacture of paper and paperboard, and with increasing importance also in the form of a wide variety of cellulose products in the textile, food, and pharmaceutical industries (A., 1992).

Historically, non-woody plants were major resources for pulp and paper production compared to woody plant. In the 19th century, an insufficient supply of the traditional raw materials of cotton and linen rags made it necessary to use wood to make paper (FAO , 2016). Today, wood fiber either hardwood or softwood are the main raw materials used for the production of pulp and paper. About 90-92% of the pulp and paper in the world are produced from wood, mostly in the developed countries (Jiménez L., 2009) such as Canada and United State of America, USA. Wood and other plant materials like pineapple wastes used to make pulp contain three main components (apart from water): cellulose fibers (desired for papermaking), lignin (a three-dimensional polymer that binds the cellulose fibers together) and hemicelluloses (shorter branched carbohydrate polymers). The aim of pulping is to break down the bulk structure of the fiber source, be it chips, stems or other plant parts, into the constituent fibers (Ethiopia, 2013).

2.1.1. World demand of pulp production

In Europe, pulp capacity is based mainly on straw. Industrial crops are the second most important raw material source in the European non-wood pulp industry, especially in the form of cotton linters. Political, economic and environmental issues favor growing special plants. More advanced utilization techniques and logistics of reed canary grass, miscanthus, sorghum, kenaf and hemp are also being developed in Europe (Leena Paavilainen, 1998). In 2013, 403 million tons of paper was produced. Among this 11% was produced from non-wood fibers. Per capita consumption was 57 and 8 and 1.56 kg/yr globally, in Africa and in Ethiopia (Yogesh M1 H. R., 2015).

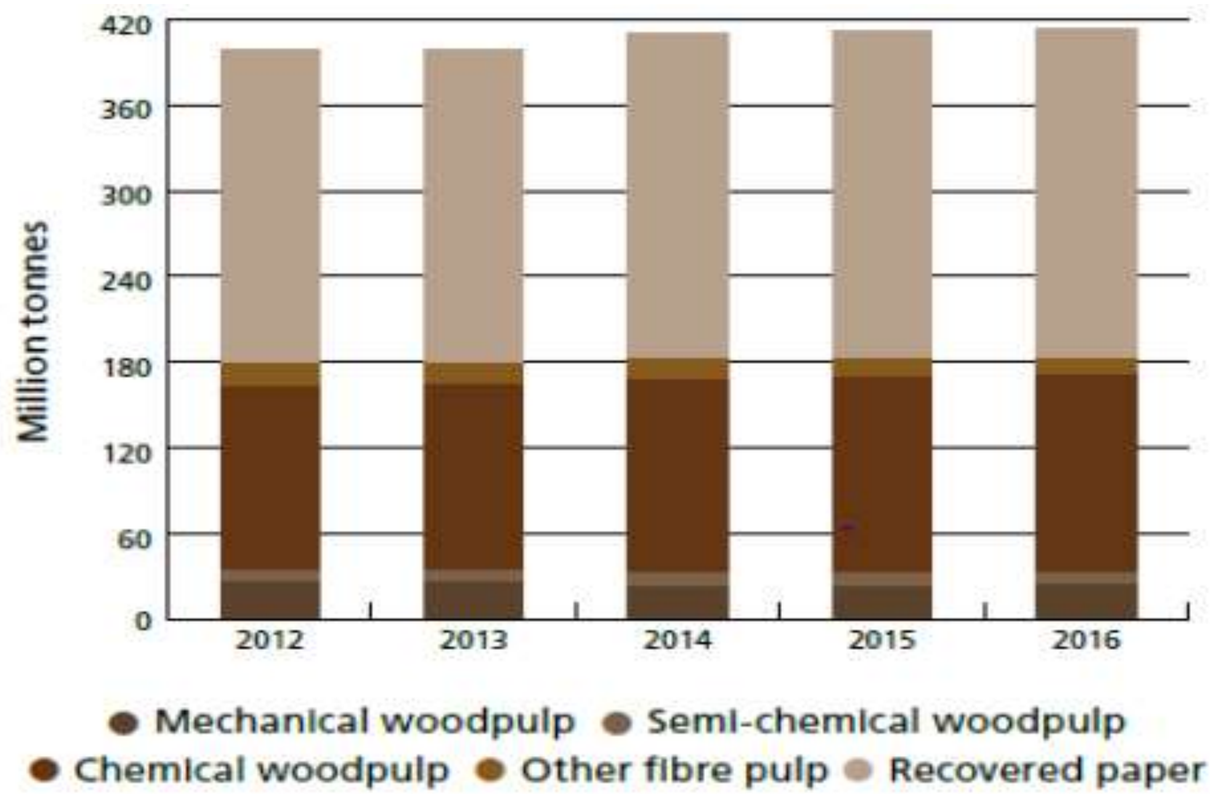


Figure 2.1World pulp production trends (FAO., 2015)

2.1.2. Local demand of Pulp production

The supply of paper in Ethiopia is dominated by imported products. Ethiopia does not produce its own pulp, but only paper. There is one paper-producing factory in Ethiopia, Ethiopian Pulp and Paper Share Company which is located in wenji. The paper mill uses imported pulp and waste paper as its raw material. The mills produce some 12,490 metric tons per annum of different qualities of finished paper and 10,241 metric tons of corrugated paper. However, the paper demand of the country cannot be satisfied by domestic production only. Therefore, Ethiopia imports not only pulp but also finished papers and corrugated papers too. According to Ethiopian central statistical authority, pulp wood used by the mill is imported at an annual cost of about 148 million Birr, and about 2.2 billon Birr is needed to import finished paper products per year (Ethiopia, 2013).

Table 2.1The amount of pulp and paper commodities imported and costs incurred (Ethiopia, 2013).

	Years					
	2010/11		2011/12		2012/13	
Commodity Imported	Amount(tone)	Cost(*1000) Birr	Amount(tone)	Cost(*1000) Birr	Amount(tone)	Cost(*1000) Birr
Pulp wood	5,583	44,850	10,346.3	119,193.3	12,637	147,082.2
Paper and paper board	73,345	1,221,765	83,182.2	1,785,735	99,642	2,128,721.2

2.1.3. Pulp properties and applications

2.1.3.1 Basic pulp properties

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 usable part of pulp is dry fiber 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.

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

Table 2.2 Basic Pulp Properties (Wiley VchVerlagGmbhand Co.KGaA W. , 2006)

No.	Parameters	Standard(ASTM)
1	Burst strength	1.9kg/cm^2
2	Breaking length	4326m
3	Tear factor	108
4	Moisture content	7-9%
5	Viscosity	250-330CP
6	Consistency	>15

2.1.3.2. Pulp application

Pulp represents the major raw material basis for two main applications: (a) for paper and board production, where the pulp fibers are mechanically modified to give a coherent sheet; and (b) for chemical conversion to products such as regenerated fibers and cellulose derivatives. The former is denoted as paper grade, the latter as dissolving grade pulp. Paper-grade pulp is by far the most dominant field of pulp production (Wiley VchVerlagGmbhand Co.KGaA, 2006*)*.

2.2. Raw materials

In the world wide, around 95% of all raw materials used by the paper industry to obtain cellulose pulp consist of hardwood or softwood. The other raw materials used for this purpose are known as “non-wood” materials. Although cellulose pulps are mainly obtained from woods, several authors report that the production of pulp from non-wood resources has several advantages such as easy pulping capability, excellent fibers for the special types of paper and high-quality bleached pulp (/Ass. E. G.). Nowadays, in paper making industry, the environmental problems have brought forward the need for cleaner technology where the new non-wood resources have been introduced to replace traditional raw materials such as wood resources with non-wood resources. The cleaner technology or green technology is applied to achieve increased production with minimum effect especially on the environment and lessen the disposal cost, steadiness risks and resource cost resulting in a declined burden on the natural environment and also increase the profits in pulp and paper-based industries.

Table 2.3 Comparison of non-wood and wood resources for pulp and paper-making (Kissinger S., 2007).

Description	Fiber resources	
	Wood	Non-wood
Cycle growth	Long growth cycles[X]	Short cycle growth [√]
Cellulose content	Higher cellulose content [√]	Lower cellulose content depends on the types of non-wood [X]
Lignin content	Contain higher lignin content [X]	Contain lower lignin content [√]
Chemical uses	Use a large volume of chemical during pulping process [X]	Use a small amount of the chemical in pulping process [√]
Time pulping	Need long time for pulping process [X]	Shorten time for pulping process [√]
Cost analysis	Expensive due to the limitation resources [X]	Cheaper cost because the abundance resources [√]
Environmental impact	Increase environmental problem such as global warming and soil erosion [X]	Reduce environmental impact which reduce the deforestation problem and improve sustainable forestry [√]

Note: [√] = advantages and [X] = disadvantages

2.3. Pineapple plant productions

Pineapple is from family of Bromeliaceae having height and width of 1-2m, which is mostly cultivated at tropical and coastal regions, mainly for fruits purpose. In India, the cultivations are about 95 million hectares of land and increasing its production. Pineapple plant has a short stem and with dark green color. First sprout of leaf looks decorative; later the size converts into 3 ft. long sword shaped and spirally arranged fibrous leaves and its edges are curved towards the cross section, which maintains the stiffness of the leaf. In Asia, India is a largest country to produce pineapple plant. It produces a huge amount of waste material. Pineapple contains rich source of bromelain and other cysteine proteases, present in different parts of pineapple.

Commercially, bromelain has been used in many food industries, cosmetics, and dietary supplements (Yogesh M1, 2015).

Figure 2.2Pineapple plant productions (Yogesh M1, 2015)

2.4. Pineapple Leaf Fibre

Yearly plenty of pineapple leaf fibre is produced but very small portion are used for feedstock. As an industrial usage the expansion of bio-composites makes the possibilities to minimize the wastage of renewable materials and promotes a non-food based market for agricultural industry. The fibre is white in colour, glossy as silk, and smooth. Medium length fibre has high tensile strength as compared to small length. Its surface is soft if compared to other natural fibres also absorbs and maintains a good colour. Pineapple leaf fibre has high strength and stiffness and is hydrophilic in nature, which has high cellulose content. Their fresh leaves yield about 2 to 3% of fibres (Yogesh M1, 2015).

Figure 2.3 Pineapple leaf fibre

2.5. Process description

- **Non Wood Preparation**; the bark is removed from in-coming logs, and these are then chipped. Sometimes, the wood arrives at the plant already chipped, meaning that this step is unnecessary.
- **Cooking**; The wood chips are heated in a solution of NaOH and Na2S in a pressure cooker, during which time a lot of the lignin (the reinforcing substance that make tree cells wood hard and 'woody' rather than soft like those of other plants) is removed from the wood. The pressure is then released suddenly, causing the chips to fly apart into fibres.
- **Pulp** Washing; the pulp is washed with water to wash out the cooking chemicals and lignin from the fibre so that they will not interfere with later process steps.
- **Pulp Screening**; A sieve is used to remove knots and clumped-together uncooked fibres from the pulp.
- **Bleaching**; this is done in two stages. Firstly 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 and finally with ClO_2 again to remove the remaining lignin.

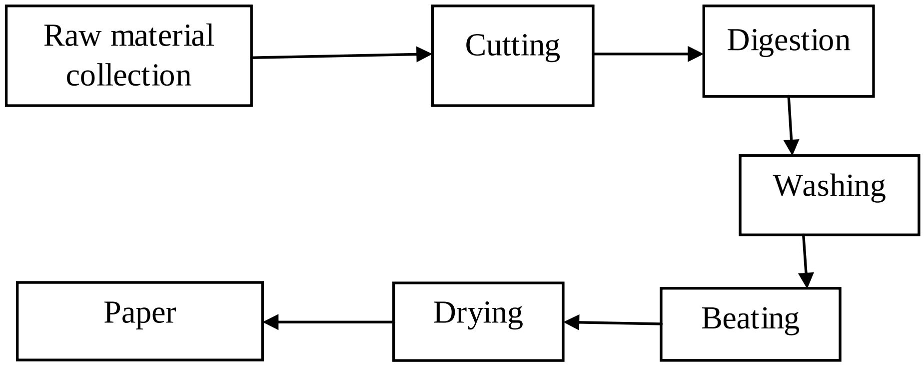


Figure 2.4 general Pulps and Paper Making Process diagram

2.6. Types of Pulping

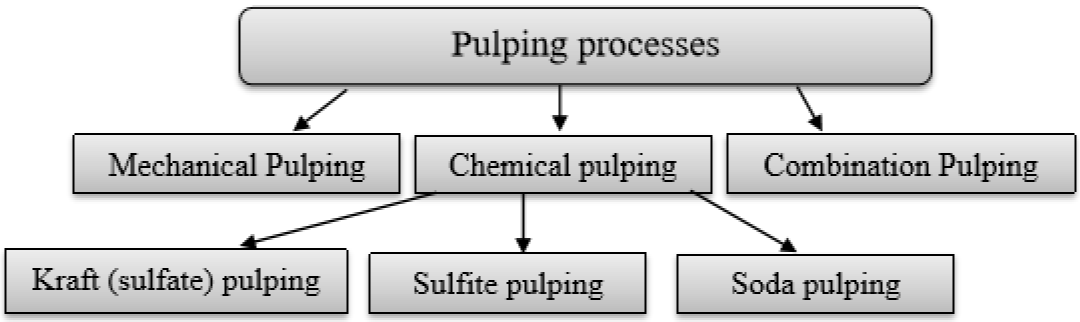


Figure 2.5Types of pulping

Pulp for papermaking can be produced from virgin fiber or from re-pulping of recycled paper. To produce virgin pulp, wood logs are first debarked and chipped. Then water and heat are added and by mechanical or chemical means the wood is separated into individual fibers (Healy, 2011).

2.6.1. Mechanical pulping

Mechanical pulping is primarily used in integrated pulp and paper mills. In this process fibers are separated through the use of mechanical energy. With a raw material conversion efficiency of 45%, mechanical pulping is considered both a simple and efficient process, but with the disadvantage that wood fibers are often damaged (Healy, 2011). Therefore, mechanical pulping is mainly used for weaker paper such as newspaper, printing paper, toweling, tissue, or paperboard.

Sometimes chemical pulp is mixed for additional strength. Electricity is the main energy input for mechanical pulping. Mechanical pulp production yields substantial amounts of heat as side product, which can be used for district heating (Worrell, 2007).

2.6.2. Chemical pulping

Chemical pulp is used both in integrated and non-integrated pulp and paper mills. Through chemical pulping, non-cellulose wood components are removed leaving the cellulose fibers intact (Bajpai, 2012). Hence, chemical pulp is better suited for high quality paper. There are mainly two different processes for chemical pulping: Kraft and soda pulping. Black liquor is an energy rich by-product of chemical pulping, which is burned in recovery boilers to produce combined heat and power (Healy, 2011).

2.6.2.1. Soda pulping process

This pulping process is entirely similar to Kraft's process. The only difference exists is the cooking chemicals used. In soda pulping process only NaOH or combination of NaOH and Na2CO3 are used.

There are different parameters that affect the soda pulping process, those are Cooking temperature, soda concentration and cooking time was used according to other researchers, industrial parameters and those available in the literature as 60-130°C, 5-30% (on dried raw material(30g-200g), 2:30min-5:30min, respectively (Smook, 1982; Khristova *et al*, 2004; Vasconcelos, 2005; Sixta, 2006; Khiari *et al*, 2009; Rodríguez *et al*, 2010).

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.

2.6.2.2. Kraft pulping process

The Kraft process is presently the most widely used cooking technology because of the following advantages:

- All wood species can be used.
- The process is tolerant to bark.
- The pulp fibers have the highest strength.
- The pulping chemicals and energy are recovered at high efficiency.
- The cooking time is relatively short.

In kraft process there are different parameter which affect the pulping process such as, Cooking temperature, sulfidity concentration, reaction time and soda concentration was used according to the results of other researchers, industrial parameters and those available in the literature as 130-180°C, 5-60% (on dried raw material(30g-250g), 30-150 min and 5-34%, respectively (Smook, 1982; Khristova *et al*, 2004; Vasconcelos, 2005; Sixta, 2006; Khiari *et al*, 2009; Rodríguez *et al*, 2010).The Kraft pulping solution called white liquor is a strongly alkaline solution (pH-14) of mostly NaOH and Na_2S. It also contains small amounts of Na_2C03, Na_2S04, Na_2S_203 and NaCl.

2.7. Lignin Reactions

Although the delignification reactions of the alkaline Kraft process are not exactly known, it is generally agreed that cleavage of the non-phenolic P-aryl ether bonds are mainly responsible for the solubilization of lignin. The presence of hydrogen sulfide ions significantly affects the delignification due to their strong nucleophilicity in comparison with hydroxyl ions. Both hydroxyl and hydrogen sulfide ions promote the cleavage of ether linkages (Sjostrom, 1993). During the Kraft process, white liquor (a blend of sodium hydroxide and sodium sulfide) promotes lignin dissolution and consequent fiber liberation. Kraft pulping occurs in three distinct kinetic phases: the initial phase, bulk phase, and residual phase. During the bulk reaction phase, 60% to 68% of the total delignification of the wood occurs. The use of sodium hydroxide and sodium sulfide offers a number of advantages when compared to other processes, especially in terms of fiber strength. However, there are also disadvantages; the major one being the loss in pulp yield caused by carbohydrate instability and degradation during the alkaline reaction (Santos, 2012).

Kraft delignification occurs by modifying the structure of lignin in two different ways to enhance its dissolution. The goal in Kraft pulping is the cleavage of lignin into alkali soluble fragments. Cleavage is affected by the following factors:

- Type of linkage
- Presence of free phenolic hydroxyl group
- Functional groups (benzyl hydroxyl, carbonyl)
- Type and amount of nucleophiles (OH^-, HS^-)
- Reaction temperature

CHAPTER THREE

3. MATERIAL AND METHODS

3.1 Materials

The major raw material used during the experimental work was pineapple wastes.

3.1.1. Equipment's used

Cutting tool; is used to cut pineapple waste in proper level into the feed. When cut banana stem to change in small pieces by using knife at the required stage as well as in cut paper at final level.

Washer; used for wash and clean the raw material from dust particles.

Beaker/flask; is a container used for stirring, mixing and heating liquids commonly used in laboratory

Sieve; is removes the remaining oversized particles (fibre bundles and contaminants) from washed pulp.

Stove; used to cooking when mix a material with chemicals to facilitate the process of lignin removal.

Dryer/oven; used to remove the moisture content of the materials.

Electronic weight; to measure the samples.

Stirrer; used for uniformly distribution of the mixed materials in the container.

3.1.2. Chemicals

Sodium hydroxide (NaOH)

Sodium sulphide (Na_2S)

Water (H_2O)

Hydrogen per oxide (H_2O_2)

3.2. Methodology

3.2.1. Experimental procedures of pulp production

3.2.1.1. Soda pulping

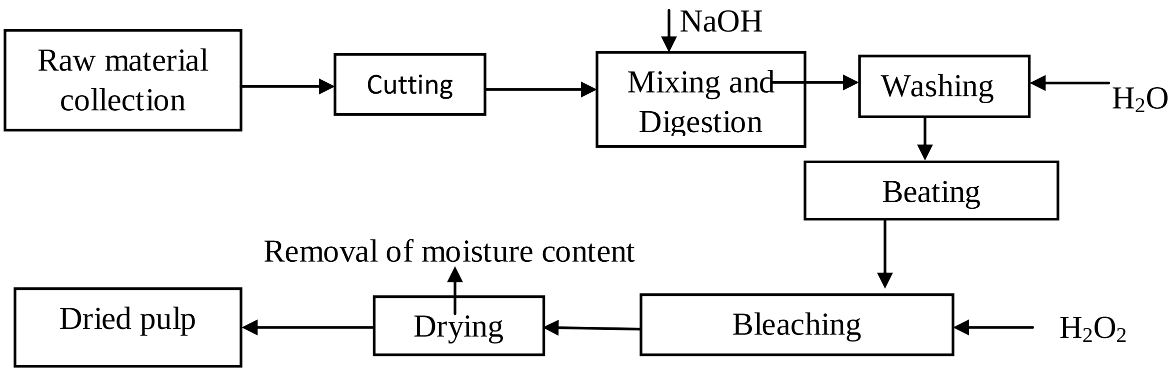


Figure 3.1. Soda pulping processes diagram

Raw material preparation

Samples of pineapple leaves were obtained from wolkite fruits market.

Figure3.2. Sample of pineapple crown, pineapple leaves removed from the crown and chipped pineapple leaves respectively

Raw material, pineapple wastes were collected and washed. Then the collected sample each was air-dried in the laboratory and there after chipped into small sizes using cutting tools, such as knife and scissors. Now the samples size became ready for pulping and this was weighed to know the amount required for pulp making. The chipped pineapple wastes were then made free from moisture in an oven at 105^{o}C.

The moisture content was also determined by the following formula:

$$moisture\ content(\%) = \frac{w_1 - w_2}{w1} * 100 \tag{3.1}$$

Where, W_1 = mass of chipped pineapple waste before drying

W_2 = mass of chipped after drying

- **Chemical composition analysis of pineapple leaves:** Chemical composition (Lignin, Ash and Cellulose contents) of pineapple leafs was determined according to Tappi Standard Test Methods (Tappi, 1985)

A) Determination of Lignin (W*lignin*): -The Lignin (defined as composition which is insoluble in 72% H2SO4) was determined by acid hydrolysis as TAPPI standard procedure (T 222 om-11). A 0.1 g of dried pineapple leaves sample was hydrolyzed with 15mL of 72% sulfuric acid at room temperature for about two hours. The hydrolyzate was then diluted with water (3000mL) to 3% concentration of sulfuric acid and placed in an autoclave at 121°C for two hours for the second hydrolysis reaction. The solid residue lignin was obtained by filtration and drying in an oven at the temperature of 105°C to constant weight. The lignin content is calculated as follows:

Wlignin=[(M1-M2)/Mu] *100%

Where: M1 is oven-dry weight (g) of filter paper,

M2 is oven-dry weight (g) of filtrated lignin plus weight (g) of filter paper,

Mu is oven-dry weight (g) of sample.

B) Determination of ash content (W*ash*): - A sample was ignited in a muffle furnace at 525 ± 25°C and burnt for 3 hours (TAPPI T211 om-12). Ash content was calculated as follows:

W*ash*=[(M1-M2)/Mu] *100%

Where: M1 is weight (g) of moisture-free sample before ignition,

M2 is weight (g) of sample after ignition,

Mu is oven-dried weight (g) of sample.

C) Determination of Cellulose (W*cellulose*):- Küschner–Hoffer method was used for the determination of cellulose. The extracted sample was cooked in a mixture of nitric acid–ethanol

(HNO_3 - C_2H_5OH with a ratio of 1:4) in a hot water bath at the temperature of 100°C with a Solid/liquid ratio of 1:15 (5g of extractives-free samples with 125mL of alcoholic nitric acid solutions under reflux during four cycles of 1 hour) (Browning, 1967). Cooking was done through four extraction cycles until the sludge became completely bleached. After each cycle, the alcoholic nitric acid solution was removed and a fresh volume was added. Its filtration and drying in an oven at the temperature of 105°C to constant weight provided Küschner–Hoffer cellulose, which was calculated as follows:

$W_{cellulose}=[(M1-M2)/Mu]*100\%$

Where: M1 is oven-dry weight (g) of filter paper funnel,

M2 is oven-dry weight of funnel + extracted cellulose (g)

Mu is oven-dry weight (g) of sample.

Preparation of cooking liquor

In this process, 30% by weight solution of NaOH was required as cooking liquor in soda pulping. If we take 300ml as basis 30% by weight gives 90gm of NaOH. This 90 grams of NaOH was dissolved in water and makeup to300ml to give required concentration of cooking liquor.

Digesting /cooking

Once the cooking liquor was prepared, 60grams of raw material (dried pineapple leaves) was taken in 300ml of cooking liquor in 1000mlbeaker. Inside the beaker, the ratio of amount of white liquor to oven dry pineapple waste was at 5L : 1kg (i.e 300ml and 60gram) respectively. Then the beaker was tied by aluminium foil after chemicals, water and pineapple wastes were added to protect loss of white liquor and pineapple waste due to eruption. The desired temperature (90 ^{o} C for soda and in kraft 155,160,165,170, and175 ^{o} C) then set and power switched on. Then the prepared pineapple waste chips were pulped using soda and Kraft method, by the parameters sulfidity(for kraft), active alkali , cooking time and cooking temperature. Pulping was performed in a laboratory cooking by stove.

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

Filtration and washing of pulp:

After cooking, brown stock and black liquor were formed. Brown stock contains pulp (cellulose and hemi-cellulose) and small amounts of lignin (reason for brown color). The black liquor contains the dissolved lignin and cooked chemicals that are unconverted and can be recovered. The mixture was then filtered using a filter 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 was again washed with water to let lignin and chemicals associated with the brown stock to dissolve in it. And, this mixture was filtered with filter and this process was repeated. It was washed several times (>=5) with to reduce the lignin content.

Bleaching:

Once filtration and washing was completed the washed pulp was dissolved in 5ml of hydrogen per oxide solution to completely remove the brown color to obtain white pulp.

Drying:

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

3.2.1.2. Kraft pulping

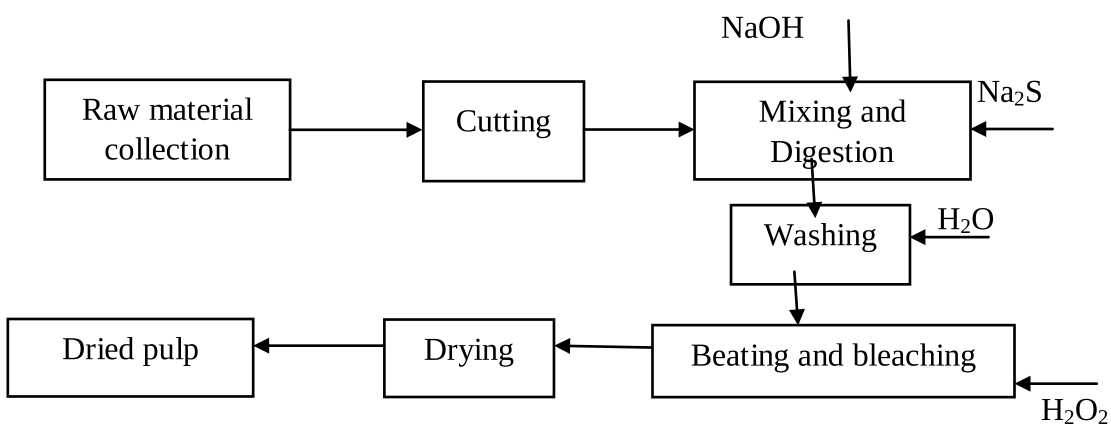


Figure 3.3 Kraft pulping process diagram

The procedure is the same as soda pulping but there is different by white liquor preparation.White liquor preparation from containing cooking chemicals, mixture of sodium hydroxide, sodium sulphide and water.

Cooking liquor or white liquor solution was prepared using different concentration of NaOH, Na_2S and Water; five (5) different kinds of white liquor were prepared.

Table 3.1 White liquor combination for kraft pulping experiment.

	Active alkali (%)	Sulfidity(%)	Repetitions
1	10	20	1
2	20	40	1
3	5	10	1
4	25	50	1
5	15	30	1
TOTAL			5

3.3. Effect of process parameter

3.3.1. Cooking Temperature Settings:

The cooking temperature as one factor was set differently as per our desire temperature in a laboratory stove temperature setting. The temperature setting of the equipment ranges from 20^{o}C to 400^{o}C. But for our Kraft pulping experiment temperature setting was done at five different levels. 155^{o}C, 160^{o}C, 165^{o}C, 170^{o}C and 175^{o}C were set as per the design of experiment (Mona Ali, 2001).

3.3.2. Cooking time:

The other factor studied in Kraft pulping is the holding time at maximum temperature. Thus after the desired cooking temperature was set in the stove, switch is on and temperature increases dramatically to its set point then stop further increasing. Cooking time at maximum temperature started to count at the time when cooking temperature reaches to maximum set point temperature. Then cooking/Kraft pulping continued to the desired cooking time.

When the required cooking time reached, the power switched off let to cool for 20 minutes in order to withdraw the sample. Therefore, five levels were used for setting cooking time. These are30, 60, 90, 120 and 150 minutes

3.3.3. Cooking liquor setting;

Active alkali and sulfidity is also another factor studied kraft pulping that can be set at five different levels. Those are 5%, 10%, 15%, 20%, 25% and 10%, 20%, 30%, 40%, 50% respectively.

3.4. Pulp Yield Determination

The objective of this experiment was to produce pulp. And pulp ideally it needs to be pure fibre. That is why we try to remove lignin and extract cellulose. When lignin removed from pineapple waste, we got fibres suitable for paper making called pulp. Since pineapple wastes are made of many chemical compositions like other woody species, it is unthinkable to get 100% pulp yield. Unfortunately in pineapple waste, sit is less than 46%, because it contains 46% of cellulose. We expect the loss of pulp yield due to cellulose degradation and fibre loss with rejects. Pulp yield expressed as percentage of the oven dry weight of the chips was determined. The pulp yield was determined by the method as per Tappi standards (Tappi, 1985).

$$pulp\ yield(\%) = \frac{moisture\ free\ weight\ of\ pulp\ from\ stove}{moisture\ free\ weight\ ofpineaple\ waste\ feed\ for\ pulping} * 100 \quad (3.2)$$

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Result for our experiment

4.1.1 Sample Analysis

A) Mass loss during Size reduction

In order to prepare raw materials for pulping, size reduction was conducted on pineapple wastes and the following mass loss was observed.

Table 4.1Pineapple waste mass loss during size reduction

No. run	Mass of pineapple wastes before size reduction(kg)	Mass of pineapple waste after drying(kg)	Mass loss(kg)
1	0.3	0.06	0.24
2	0.3	0.064	0.236
3	0.3	0.066	0.234

As it can be seen from the above table, the average mass loss is 0.237kg from 0.3 kg of pineapple wastes. Therefore, (0.237/0.3)*100 = 79% of mass loss was obtained during size reduction and dried of pineapple wastes.

B) Moisture content determination of pineapple wastes

The pineapple wastes were collected in July, 2021, after two Weeks the moisture content of pineapple wastes was determined using equation 3.1 and the results are presented in the following below.

$$\text{moisture content}(\%) = \frac{w_1 - w_2}{w1} * 100 \qquad (3.1)$$

W_1 =0.3kg and W_2 =0.06kg

Moisture content (%)=[0.3-0.06/0.3] *100% =80%

C) Chemical composition of pineapple leaves

Then to analyse chemical composition of pineapple leaves in our experiment result show in the following table below.

Table 4.2.Chemical composition of Pineapple wastes (Biochemical Engineering and Biotechnology, 2015)

Agro waste	Cellulose (%)	Ash content (%)	Lignin content (%)	Moisture content (%)
Pineapple waste/leaf	65	1.2	11.5	80

The results of the chemical composition analysis of pineapple wastes showed that cellulose, which is the major chemical component of fibre wall make up approximately 65%. Cellulose is the component that makes the fibre inside non-wood materials stronger. These are important parameters in determining the suitability of a raw material for pulp and paper making. The `quality of fibre produced from non-wood materials depends on the contents of cellulose.Higher contents of cellulose can provide stronger fibres, thereby increasing the quality of the paper produced.

The result also shows that pineapple waste contains low lignin of approximately 11.5%. Low lignin content has been reported as one of the advantages inherent in the use of non-wood materials for pulp production as lignin functions as adhesive to bind the cellulose fibre together. Also, materials with low lignin contents require relatively small amount of chemical for pulping (Oluwadare, 2007). Lower lignin content is easier to discard from the pulp, and the paper that will be produced is of greater quality compared to that from other non-wood materials.

Pineapple waste was found to have low ash content (1.2%). The function of ash content is to show the absence or presence of other materials slightly or in combination. The low ash content indicates that pineapple leaf pulp has the potential to produce good quality paper. Pineapple leaf has very high moisture content (80%). This high moisture content will affect the mechanical and surface properties of the paper produced which indicates a less dimensional stability against the grain.

4.1.2. Results for soda pulping

Table 4.3 moisture content and percent yield of pineapple waste soda pulp.

No. run	Active alkali (%)	Max. pulping temperature(^oC)	Time@max. Temperature(min)	Moisture content (%)	Pulp yield (%)
1	15	90	4:30	20	30

During our laboratory test the result of soda pulping required more time and concentration of alkali to degreed lignin content of pineapple leaves due to weak cooking liquor as compared to kraft pulping. And also to gets/gives low quality of pulp.

Effect of cooking time on mass of pulp

Mass of pulp is affected by cooking time, temperature, concentration, pineapple chips size and other components in the pineapple. But pineapple chips size and other components in the pineapple is insignificant factor in our laboratory experiment. Concentration sodium hydroxide plays a great role on the mass yield of pulp using soda production process. The production rate is fast at the beginning of the production but gets slow gradually. The reason is that when the pineapple chips is cooked to the stove 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.

Effect of cooking temperature on mass of pulp

Temperature has a significant impact on reaction rate of soda cooking chemicals. As the temperature in the early portion of the cook increases, significantly more alkali is consumed by chemical reaction at the expense of chemical diffusion in to fibre. Higher temperature cooking of pineapple waste damages pulp yield. This is because rate of delignification is much higher at higher temperature as compared to lower temperature and at higher temperature we get lower yield because higher temperature also affects and damages the fibre which contributes in decreasing the yield.

Effect of concentration on mass of pulp

Concentration of sodium hydroxide 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.

4.1.3. Result for Kraft puling

Table 4.4 percent yield of pineapple waste kraft pulp.

No. run	Active alkali (%)	Sulfidity (%)	Max. pulping temperature(^{o}C)	Time@max. Temperature(min)	Pulp yield (%)
1	5	10	165	90	34.6
2	15	30	155	60	41.6
3	10	20	175	120	36.2
4	20	40	160	30	39.2
5	25	50	170	150	38.7

The maximum pulp yield obtained was 41.6% at the cooking conditions of 15% and 30% of active alkali and sulfidity respectively and at 155^{o}C temperature and 60 minutes of holding time. The minimum pulp yield 34.6% was found at 5% active alkali charge and 10% sulfidity cooked at 165^{o}c for 90 minutes.

Effects of Active alkali on pulp yield

Percent yield of pineapple waste pulp is affected by active alkali, sulfidity, temperature, and holding time at maximum temperature. Active alkali charge plays a great role on the percentage yield of pineapple waste pulp. Figure 4.3 shows that the pulp yield increases as the active alkali charge increases from 5% to 15% of oven dry pineapple waste. But unfortunately pulp yield decreases as active alkali charges increases above 15%.

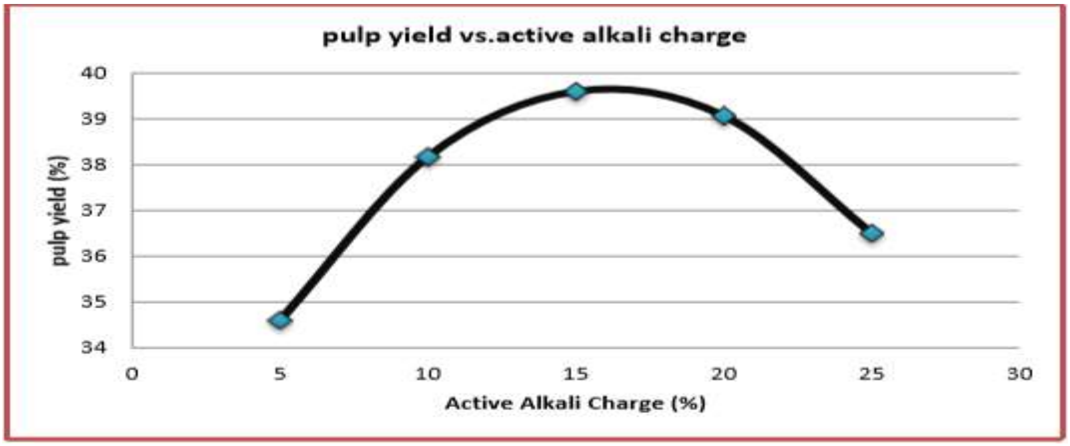


Figure 4.1 Effects of active alkali charge vs pulp yield from pineapple waste graph

Even though Active alkali (NaOH), concentrations of chemical in white liquor, had a positive effect on delignification, it had negative impact on pulp yield when charged at higher concentrations. Higher Active Alkali concentration accelerates the delignification rate and in contrast degrades cellulose which is the main content of pulp.

Effects of sulfidity on pulp yield

In Kraft pulping, sodium sulphide (Na_2S) acts as a catalyst and interference of other side reactions. As it can be seen from figure 4.4, increasing sulfidity from 10% to 30% increases pulp yield. However, increments of sulfidity from 30% to 50%, decreases the pulp yield. Off course active alkali, temperature and time was kept at their central points.

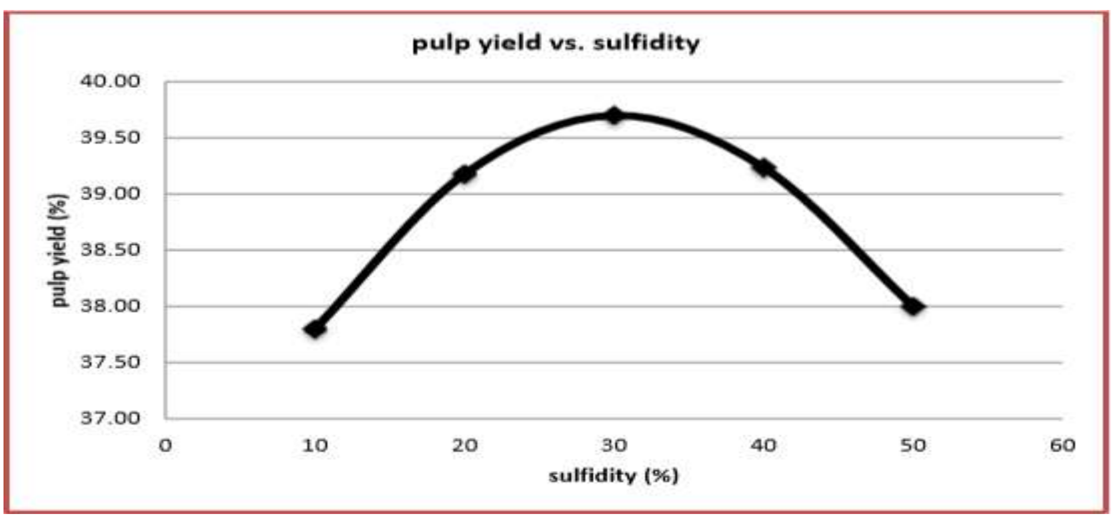


Figure 4.2 Effects of sulfidity vs pulp yield of pineapple wastes graph

This is because at lower concentrations of sodium sulphide, the speed of the reaction will slower and it takes longer time to extract lignin from the pineapple leaves. The other reason is that at lower concentrations of sodium sulphide there is a chance for side reactions to occur. On the other hand at higher percentage of sulfidity, Kraft pulping will completed in shorter time and farther cooking will damage the product then yield reduced.

Effects of temperature on pulp yield

As it can be observed from figure 4.3, temperature has a negative effect on pulp yield of pineapple wastes. When the temperature increases from 155^{o}C to 175^{o}C by keeping other three factors at their central points, pulp yield of pineapple waste decreases. Temperature has a significant impact on both the diffusion rate and reaction rate of Kraft cooking chemicals. As the Temperature in the early portion of the cook increases, significantly more alkali is consumed by chemical reaction at the expense of chemical diffusion in to fibre. As the rate of alkali consuming reactions is highest at the beginning of the cook, increased temperatures in the impregnation stage will significantly reduce the amount of alkali available for diffusion. Higher temperature cooking of pineapple waste damages pulp yield. This is because rate of delignification is much higher at higher temperature as compared to lower temperature and at higher temperature we get lower yield because higher temperature also affects and damages the fibre which contributes in decreasing the yield. Higher temperature also affects the lignin condensation because at higher temperature, chemical penetration takes place rapidly which also reduces the yield.

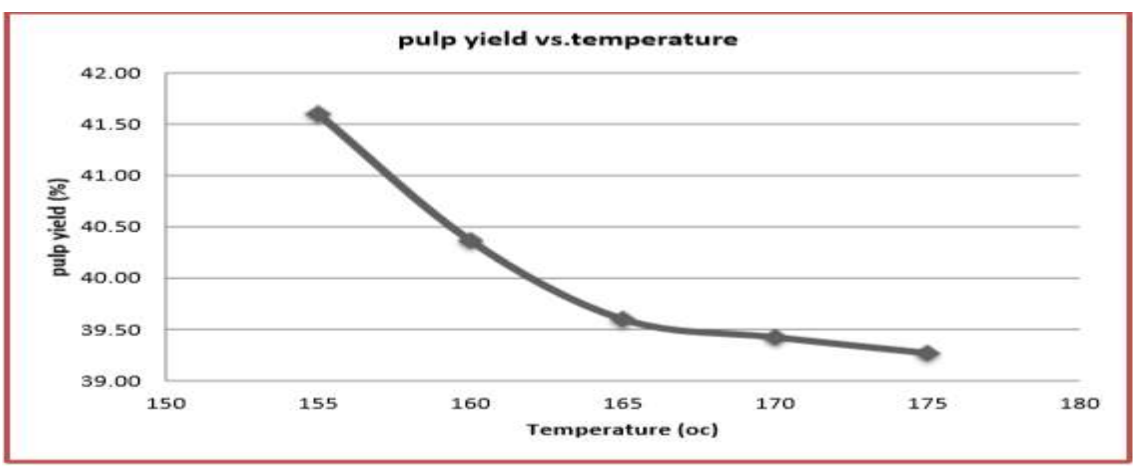


Figure 4.3 Effects of temperature vs pulp yield of pineapple wastes graph

Effects of cooking time on pulp yield

Figure 4.4 shows the effect of cooking time on pulp yield of pineapple waste was not much incredible as other three factors. Rather cooking time has less effect on pulp yield. Increasing cooking time from 30 to 60 minutes increase pulp yield. But further cooking the pineapple waste was downs the pulp yields again even though it is not significant figure.

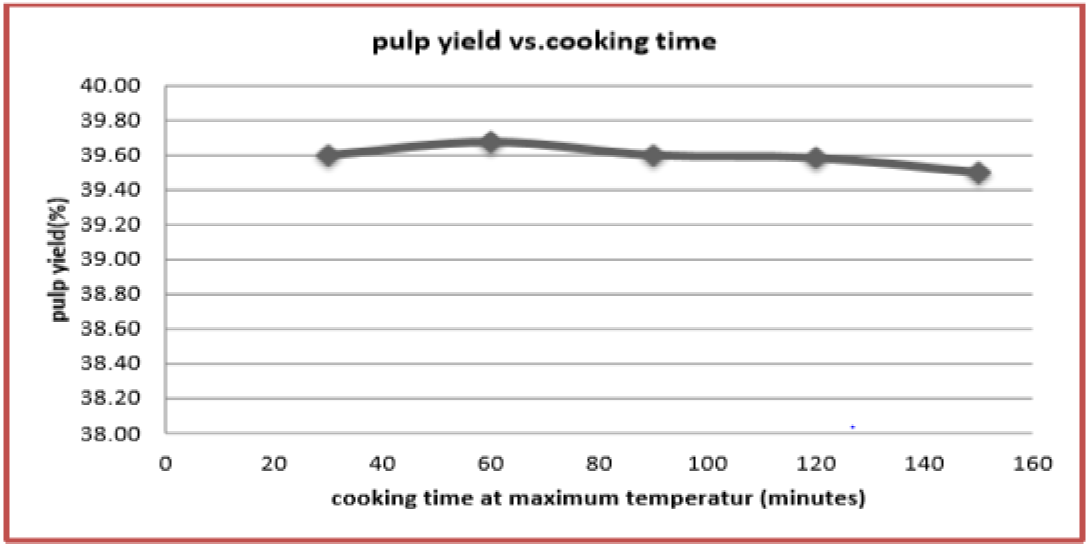


Figure 4.4 Effects of cooking time at maximum temperature vs pulp yield of pineapple waste graph

CHAPTER FIVE

5. MATERIAL AND ENERGY BALANCE

5.1. Material and energy balance in laboratory scale

Material quantities, as they pass through processing operations, can be described by material balances. Such balances are statements on the conservation of mass. Similarly, energy quantities can be described by energy balances, which are statements on the conservation of energy. If there is no accumulation, what goes into a process must come out. Material and energy balances are very important in an industry. Material balances are fundamental to the control of processing, particularly in the control of yields of the products.

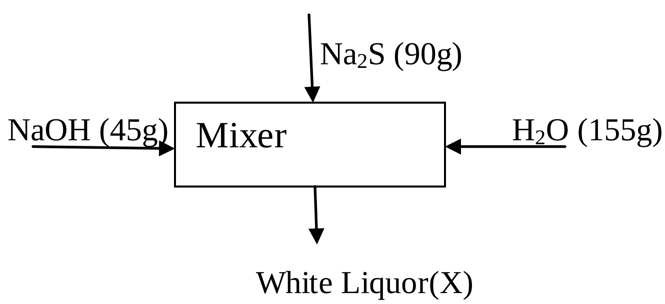
5.1.1. Material balance in laboratory scale

From the general material balance

$$Accumulation = input_{total} - output_{total} - consumption + generation$$

Basic Assumptions:

- There is no reaction so generation, consumption, and accumulation terms are zero
- Steady state for all calculations i.e. Input=output
- From give data 60gm of raw material and 300ml white liquor
- **Component material balance on mixer**



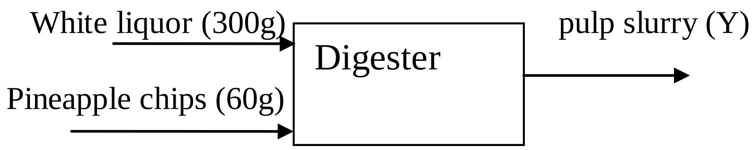
Mass in = mass out

Mass of NaOH + mass of Na_2S + mass of water = mass of white liquor(X).

45g (NaOH)+90g(Na_2S)+155g(H_2O)=X

X=300g

- **Component material balance on digester**

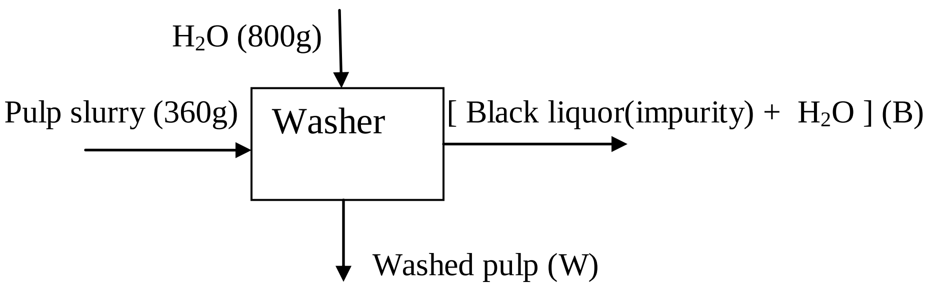


Mass of pineapple waste chips + mass of white liquor = mass of pulp slurry(Y)

60g+300g=Y

Y=360g

- **Component material balance on diffuser washer:**



Mass of water + mass of pulp slurry = mass of washed pulp + mass of black liquor

Assume the pulp slurry is 1.5% impurity and the efficiency of washer is 98.5%

Over all material balance on washer

360g+800g=W+B, 1st to calculate impurity (black liquor)

The impurity removed = (1160*0.985*0.015)g=17.2g

Pulp slurry=impurity removal+ washed pulp

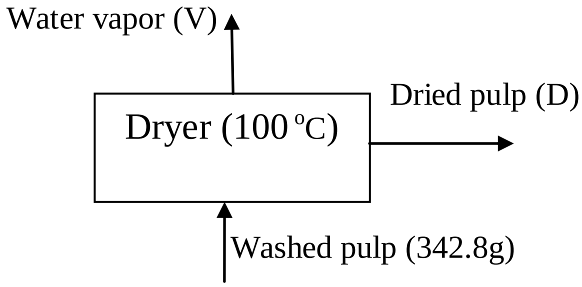
360g=17.2g+ (W), W=342.8g

The impurity of pulp slurry=0.015*1160g=17.4g

So, the impurity remains after washing =17.4g-17.2g=0.2g

By above equation 360g+800g=342.8g+B, B=817.2g

- **Component material balance on dryer:**



The pineapple leaves after drying loss its weight from 85%-95%

Taking 92.5% weight loss. So mass in =mass out

Washed pulp =dried pulp +water vapor

But water vapor (weight loss of after drying) =0.925*342.5g

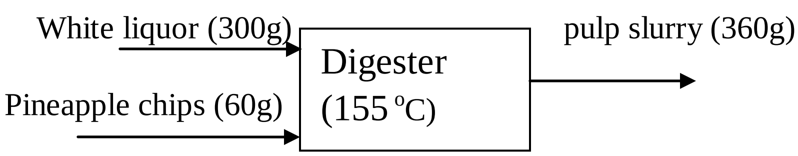
$$V = 317.2g$$

So, dried pulp=washed pulp-water vapor

D= (342.8-317.2)g, =25.6g

5.1.2. Energy balance in laboratory scale

- **Component energy balance on digester**



Specific heat capacity from table at differet temperature

At rom temp (25 ^{o}C) =specific heat capacity (1.235KJ/Kg. ^{o}C)

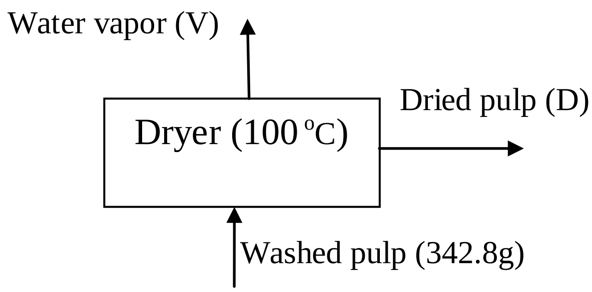
At temp (155 ^{o}C) =2.406KJ/Kg. ^{o}C

Energy in=Energy out

$$Q=MCP\Delta T=360g*2.406KJ/Kg.\,^{o}C*(155-25)\,^{o}C$$

$$Q=112.6KJ$$

- **Component energy balance on dryer:**



Specific heat capacity from table at different temperature

At rom temp (25 ^oC) =specific heat capacity (1.235KJ/Kg. ^oC)

At temp (100 ^oC) =1.6KJ/Kg. ^oC

Energy in=Energy out

$$Q=MCP\Delta T=342.8g*1.6KJ/Kg.\ ^oC*(100-25)\ ^oC$$

$$Q=41.136KJ$$

5.2. Material and energy balance in industrial scale

5.2.1 Material balance in industrial scale

From the general material balance

$$Accumulation = input_{total} - output_{total} - consumption + generation$$

Basic Assumptions:

- There is no reaction so generation, consumption, and accumulation terms are zero
- Steady state for all calculations i.e. Input=output
- Production capacity of the plant is =10tone/day
- Plant working time is=300day/year

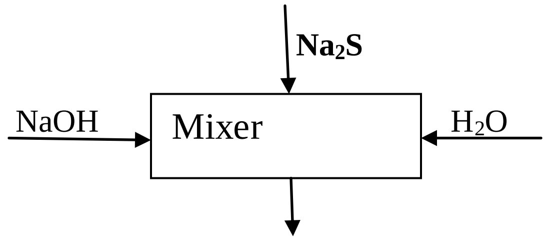
Given data:

- Density of pineapple chips(ρ) = 0.38g/cm^3= 380Kg/m^3
- From 60gm of raw material and 300ml white liquor, we have produced 25gm of pulp.

Therefore amount of raw material required to produce 10tone/day is:

$$Amount\ of\ pineapple\ waste\ chips = \frac{60g * 10ton/day}{25g} = 24\ ton/day$$

- **Component material balance on mixer**



Mass in = mass out

Mass of NaOH + mass of Na_2S + mass of water = mass of white liquor.

From the data, 60 gram of pineapple chip was used for 300 gram of white liquor, 60 gram pineapple chips = 300 gram white liquor

24 tons/day = X

X= 24tons/day*300 gram white liquor/60gram pineapple chips.

= 120tons/day of white liquor is required.

The white liquor contains 75% water, 25%NaOH+Na2S or 20% Na2S 5% NaOH.

Mass of water = 75% of white liquor

= 0.75 * 24tons/day

= 18tons/day

The volume of water can be calculated as:

$V_{water} = m_{water}/\rho_{water}$

= 18tons/day * 1000Kg/tones/1000Kg/m3

= 18m3/day

Mass of NaOH= 5% of white liquor

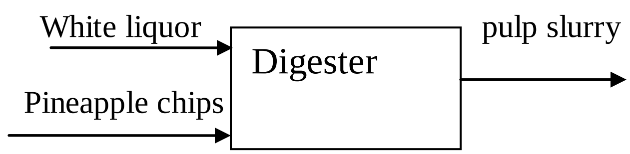
= 0.05 * 24tons/day,   = 1.2tons/day

Mass of Na_2S= 20% of white liquor

= 0.2 * 24tons/day

= 4.8tons/day

- **Component material balance on digester**

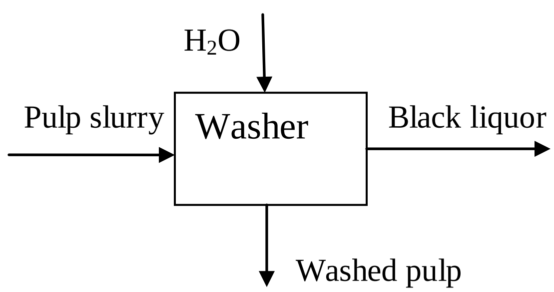


Mass of pineapple waste chips + mass of white liquor = mass of pulp slurry

24tons/day + 120tons/day = mass of pulp slurry

Mass of pulp slurry = 144tons/day

- **Component material balance on diffuser washer**:



Mass of water + mass of pulp slurry = mass of washed pulp + mass of black liquor but, the ratio of pineapple chips to water was 1:3 in a washer or washing tank:

Mpineapple waste chip/Mwater = 1/3

Mwater = Mpineapple chip*3

= 3*24tons/day

= 72tons/day

The volume of water to wash the pulp is calculated as:

$V_{water} = m_{water}/\rho_{water}$

= 72tons/day * 1000Kg/tons/1000Kg/m^3

= 72m3/day

for 1tonne of pulp, 7 tons of black liquor is produced. Then:

1ton of pulp= 7 tons of black liquor

10tonne of pulp= X

X= 10tons/1tonne * 7tons black liquor

= 70tons of black liquor is produced.

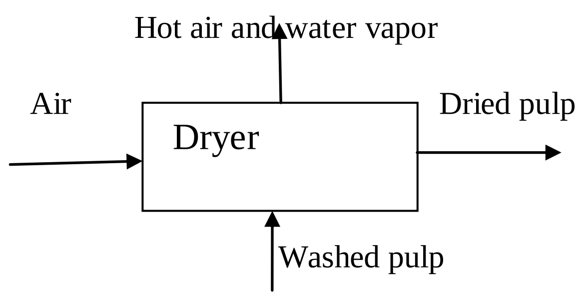
Then mass of washed pulp was:

72tons/day + 80tons/day = $m_{\text{washed pulp}}$ + 72tons/day

Mwashed pulp= (152-72) ton/day

Mwashed pulp = 80tons/day

- **Component material balance on dryer**:



Mass of air + mass of washed pulp= mass of dried pulp + mass of evaporated water with hot air

From the literature for one Kg of air dried one mega gram/tons of pulp. That is; the optimum value of air to pulp ratio is in a range of 1-1.5.

1Kg air= Mg= 1ton of dried pulp

X = 10tons dried pulp

X= 1Kg air * 10 tons/1tons

= 40Kg of air is required.

Then mass of evaporated water and hot air was:

40 Kg air + 120tons/day=$m_{\text{evaporated water and hot air}}$ + 10tons/day

$m_{\text{evaporated water and hot air}}$ = (160-10)tons/day

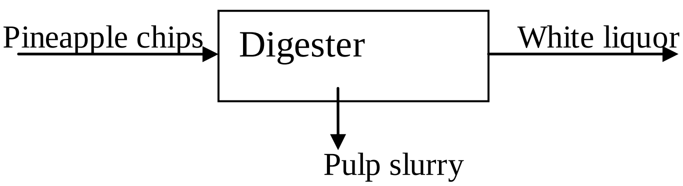
$m_{\text{evaporated water and hot air}}$= 150tons/day

Table 5.1 summary on material balance

Item	Mass flow rate(ton/day)
White liquor	120
Black liquor	70
Pulp slurry	144
Whished pulp	80
Dried pulp	10

5.2.2. Energy balance in industrial scale

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:

$E_{in} + E_{generation} + E_{consumption} = E_{out} + E_{accumulation}$

$E_{in} = E_{out}$, $Q = \dot{m}Cp\Delta T = \dot{m}Cp\,(T - T_{ref})$

$Q = [(\dot{m}_{pineapple\ chip} * Cp,pineapple_{\ chip}) + (\dot{m}_{white\ liquor} * Cp_{white\ liquor})] * \Delta T$

Given that:- reference temperature is at 20°C

$CP_{pineapple\ chip}$ at 20 temperatures is obtained by interpolating the Temperature between 0 and 100 since

Cp (KJ/Kg K)	temperature (°C)	
1.113	0	
X	20	X=1.210KJ/Kg K
1.598	100	

Cp_{H2O} = 4.18KJ/Kg K

Cp_{NaOH} = 28.23J/mol K= 0.70575KJ/Kg K

Cp_{Na2S}= 0.102 + 0.003869 T (K) but the room temperature is 20 or 293.15K

So that; Cp_{Na2S}= [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 sulfide and sodium hydroxide.

$$Cp_{\text{white liquor}} = \frac{CpH2O\ +\ CpNaOH\ +\ CpNa2S}{3}$$

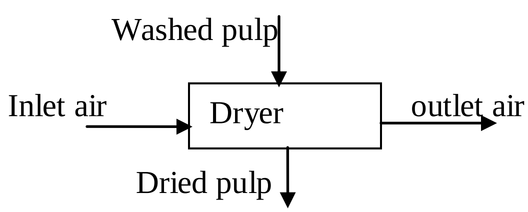
$$= \frac{4.18KJ/Kg\ K + 0.70575KJ/Kg\ K + 1.2362KJ/Kg\ K}{3} = 2.04065KJ/Kg\ K$$

Then the amount of heat required for the digester was:

Q= [(16tons/day * 1.21KJ/KG K) + (133.3tons/day * 2.04065KJ/Kg K)] * (399.1 -293.15) K

= [(16tons/day * 1000kg/tons * 1day/86,400sec) + (133.3tonne/day*1000Kg/tons* 2.04065KJ/Kg K * 1day/86,400sec)] * 106 K = 353.34KW

- **Energy balance on dryer**



Assume that during drying process there is no heat generation, consumption and accumulation. So that, the energy balance was:

$E_{in} + E_{generation} + E_{consumption} = E_{out} + E_{accumulation}$

$$E_{in} = E_{out},\ Q= \dot{m}Cp\ T= \dot{m}Cp\ (T-T_{ref})$$

Q= [($\dot{m}_{\text{pineapple chip}}$ * $Cp_{\text{pineapple chip}}$) + ($\dot{m}_{\text{white liquor}}$ * $Cp_{\text{white liquor}}$)] * ΔT

Given: - moisture content of washed pulp=0.816

Inlet temperature of washed pulp= 20 = 293.15 K and Reference temperature= 0

Moisture content of dried pulp= 0.0918

Mass flow rate of washed pulp= 80tone/day

Mass flow rate of dry air= 4kg/day= 0.0000463Kg/sec

Inlet temperature of air= 150 = 413.15 K

Outlet temperature of air= 30 = 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 is calculated by interpolating between 0 and 100:

Cp (KJ/Kg K)	temperature (^oC)	
1.11	0	
X	30	X= 1.2585KJ/Kg K
1.598	100	

For the wet solid or interring to the dryer, the mass flow rate of water was:

$\dot{m}_{water}$ =mc * $\dot{m}_{washed\ pulp}$, where mc is the moisture content.

= 0.816*80tons/day * 1000Kg/tons * 1day/86,400sec

= 0.75Kg/sec but, the mass of dry solid is 0.046Kg/sec or 4tons/day

Energy balance on inlet air (hot air stream)

Q= ṁCp*ΔT= heat contained by incoming dry hot air + heat contained by water vapor with dry air., Q= [($\dot{m}_{dry\ air}$ * $Cp_{dry\ air}$) + ($\dot{m}_{water\ vapor\ in\ dry\ air}$ * $Cp_{water\ vapor}$)] *ΔT

Assume that the mass of water vapor in dry air is negligible. So that, the amount of heat required was: Q= ($\dot{m}_{dry\ air}$ * $Cp_{dry\ air}$) *ΔT

= 0.0000463Kg/sec * 1.005KJ/Kg K * (413.15-273.15) K, = 0.007 KW

Energy balance on wet solid (washed pulp)

Q= ṁCp ΔT, = [($\dot{m}_{water}$ * Cp_{water}) + ($\dot{m}_{dry\ pulp}$ * $Cp_{dry\ pulp}$)] *ΔT = [(0.75Kg/sec * 4.18KJ/Kg K) + (0.0000463Kg/sec * 1.2585KJ/Kg K)] * (293.15-273.15) K, = 62.7KW

Amount of heat required for the drying will be:-QT=$Q_{dry\ air}$ + $Q_{washed\ pulp}$

= 0.007 + 62.7KW, = 62.707KW

Table 5.2 Summary on energy balance

Equipment	Flow rate Q(KW)
Digester	353.34
Dryer	62.707

CHAPTER SIX

6. ECONOMIC ANALYSIS

6.1 Purchased equipment cost

A. Cost of mixer: From table 6.2 in the middle of 2004 Coulson and Richardson

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

Cost in 2004

Cost index----------1900

Index---------------0.5

Then the purchased equipment cost (Ce) is calculated as:

$Ce = CS^n$, Where Ce = purchased equipment cost, ETB

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

C = cost constant from table6.2 and n = index for that type of equipment.

1hp = 0.7455Kw

1184.62hp = X

X =1184.62hp*0.7455Kw/1hp = 883.1342Kw.

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

$C_e = CS^n$ = 1900*750.5 = 16,454.48$ for purchased cost in 2004.

Cost in 2020 = cost in 2004 * (index in 2020/index in 2004)

Year	Cost index
2003	108
2004	112
2020	X

By extrapolating index of 2020 = 176

The cost in 2020 = 16,454.48$*176/112= 25,857.04$

Convert to the ETB: i.e . 1$ = 38.2 ETB.

Cost of mixer = 25,857.04$*38.2ETB = 987,738.928ETB

B. Cost of digester: From table 6.2 in the middle of 2004 G.C.

Type = constructed from steel

Size = $96.437m^3$

But, the size range is 1-50 so, it needs to use the maximum size from the range

Cost = 2400$

Index = 0.6

Purchased digester cost in 2004(Ce):

$C_e = C*S^n$ = $2400\$*(50)^{0.6}$ = 25,095.349$. But the purchased cost in 2020 computed as;

The cost from processing engineering is:

Year	Cost index
2003	108
2004	112
2020	X

By extrapolating index of 2020 = 176

The cost in 2020 = cost in 2004*(cost index 2020/cost index 2004)

= 25,095.349$*(176/112) = 39,435.548$

= 39,435.548$*(38.2ETB/1$)

= 1,506,439.156ETB

N.B: one batch digester is required for reserve.

Cost of digester = 2 *1,506,439.156ETB = <u>3,012,878.312ETB</u>

C. Cost of diffuser washer:

Size of diffuser washer is $7.55m^3$cost = 2400

Size range 1-50 index = 0.6

Purchased equipment cost in 2004G:

$C^e = CS^n = 2400\$*(7.55)^{0.6}$

Cost in 2004 = 8,071.968$,

Cost in 2020 = cost in 2004*(cost index 2020/cost index 2004)

The cost index from processing Engineering:

Year	Cost index
2003	108
2004	112
2020	X

After extrapolating cost index in 2020 = 176

Cost in 2020 = 8,071.968$*(176/112) = 12,684.521$

Cost of diffuser washer = 12,684.521$*(38.2ETB/1$) = <u>484,548.702ETB</u>

D. Cost of screen conveyor dryer:

The area of the screen conveyor dryer is $4m^2$ or 43.1 ft^2.

From the Appendix 1, Equipment Cost Estimates, the cost in 1987 G.C can be determined by extrapolating:

Area(ft^2)	Purchased Cost ($)*1000
5000	160
6000	170
43.1	X

After extrapolating the cost in 1987= 110,431$

To an early of 1987, to a Chemical Engineering, the index number is 320.

Year	Index
1987	320
2004	112
2020	X

X=-83.76=83.76(i.e. Neglecting the negative sign of index case of calculation and interpolation).

Cost in 2020 = cost in 1987*(Cost index in 2020/cost index in 1987)

= 110,431$*(83.76/320)

= 28,905.31$*(38.2ETB/$)

= 1,104,182.842ETB

E. Cost of water storage tank:

i). Cost of water storage tank-1: From table 6.2 in the middle of 2004 storage tank floating roof.

Size =468.16m^3 Cost = 4,350$

Size range = 50-8000 Index = 0.55

Purchased equipment cost of water tank in 2004G.C is

$C^e = CS^n = 4350\$*(468.16)^{0.55} = 127,998.87\$$

Cost in 2020 = cost in 2004*(cost index 2020/cost index 2004)

= 127,998.87$*(176/112)

= 201,141.08$ = 7,683,589.31ETB

ii). Cost of water storage tank-2: from table 6.2 in the middle of 2004 storage tank floating roof.

Size =200.64m^3 Cost = 4350$

Size range = 50-8000 Index = 0.55

Purchased equipment cost of water tank in 2004 is:

$C_e = CS^n = 4350\$*(200.64)^{0.55}= 80,319.11\$$

Cost in 2020 = cost in 2004*(cost index 2020/cost index 2004)

= 80,319.11$*(176/112)

= 126,215.744$ = 4,821,441.421ETB

F. Cost of surplus tank: - Surplus tank is a vertical process tank constructed from carbon steel at 270m^3 capacity with a size range of 50-800m3.

Purchased equipment cost is calculated as: - $Ce = CS^n$

Cost in 2004 = 4350$ and Index = 0.55

$C_{2004} = 4350 * (270)^{0.55} = 94{,}566.938\$$

Cost in 2020= cost in 2004*(index in 2020/index in 2004)

Year	Cost index
2003	108
2004	112
2020	X

After extrapolating cost index of 2020=176

$C_{2020} = 94{,}566.938\$ * (176/112) = 148{,}605.188\$$

Surplus tank cost =148,605.188$*(38.2ETB/1$)

= 3,576,718.192ETB

G. 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 58m^2 (271.2ft^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 ($)
50	55000
58	X
60	65000

After interpolating cost in 2002= 63,000$

$C_{2020} = C_{2002}$*(cost index in 2020/cost index in 2004)

From Coulson and Richardson process engineering figure the index in 2002 is 106 and in 2020is 160 (found by extrapolation).Then

$C_{2020} = 63{,}000\$ * (160/106) = 87{,}962.26\$$

Dearator cost = 95,094.34$*38.2ETB/1$ = 3,632,603.77ETB

H. Cost of boiler: - The capacity of electrical boiler is 166.2kg/hr (366.89ib/hr). From Kostnads data process utrustning in 2002 the purchased equipment cost for this heat transfer area will be obtained by extrapolation method.

Capacity (ib/hr)	purchased cost ($)
50000	200000
366.89	X
10000	100000

After extrapolating cost in 2002= 75,917.225$

C_{2020}= C_{2002}*(cost index in 2020/cost index in 2002)

From Coulson and Richardson process engineering figure the index in 2002 is 106 and in 2020 it is 160 (found by extrapolation).Then:

C_{2020}= 75,917.225$*(160/106) =114,635.01$

Boiler cost= 114,635.01$*(38.2ETB/1$) = 4,379,057.372ETB

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

=(987,738.928+3,012,878.312+484,548.702+1,104,182.842+7,683,589.31+4,821,441.421+3,576,718.192+3,632,603.77+4,379,057.372)ETB= 29,682,758.849ETB.

I. 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 42.94gpm. The pump purchased cost from Kostnads data process utrustning in 2002 is

Capacity (gpm)	purchased cost($)
10	3000
42.94	X
100	4000

After interpolating the cost in 2002 = 3,366.00$

The Cost in 2020 = cost in 2002*(cost index 2020/cost index 2002)

=3,366.00$*(160/106)

= 5,082.66$ =194,157.612ETB

Pump-2: for the white liquor with a capacity of 52.430gpm.

The pump purchased cost from Kostnads data process utrustning in 2002 is;

Capacity (gpm)	purchased cost($)
10	3000
52.48	X
100	4000

After interpolating the cost in 2002 = 3,471.36$

Cost in 2020 = cost in 2002*(cost index 2020/cost index 2002)

= 3,471.36$*(160/106)

= 5,241.75$ =200,234.85ETB

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 2002 is;

Capacity (gpm)	purchased cost ($)
10	3000
18.4	X
100	4000

After interpolating the cost in 2002 = 3,093.33$

The Cost in 2020= cost in 2002*(cost index 2020/cost index 2002)

= 3,093.33$*(160/106)

= 4,670.928$ = 178,429.46ETB

Pump-4: to drive the digested wood chips with a capacity of 48.255gpm.

The pump purchased cost from Kostnads data process utrustning in 2002 is:

Capacity (gpm)	purchased cost ($)
10	3000
48.255	X
100	400

After interpolating the cost in 2002 = 3,425.06$

The Cost in 2020 = cost in 2002*(cost index 2020/cost index 2002)

= 3,425.06$*(160/106) = 5,171.75$ =197,560.85ETB

Pump-5: to drive the pulp to the washer with a capacity of 21gpm. The pump purchased cost from Kostnads data process utrustning in 2002 is;

Capacity (gpm)	purchased cost ($)
10	3000
21	X
100	4000

After by interpolating the cost in 2002 = 3,122.22$

The Cost in 2020 = cost in 2002*(cost index 2020/cost index 2002)

= 3,122.22$*(160/106)

= 4,714.55$=180,095.894ETB

Cost of pump for boiler: the type of pump is centrifugal pump because water is not viscous, low pressure drop and low flow of velocity.

i. Pump one: - from river to surplus tank with 190 gpm capacity. The pump purchased cost from Kostnads data process utrustning in 2002 is:

Capacity	purchased cost
100	4000$
1000	4000$
190	X

After interpolating cost in 2002= 3,611.2$

$C_{2020} = C_{2002}$*(cost index in 2020/cost index in 2002)

C_{2020} = 3,611.2$* (160/106)

Centrifugal pump cost = 5,452.912$ = 208,301.238ETB

ii. Pump two: - from surplus tank to dearator with 46 gpm capacity. The pump purchased cost from Kostnads data process utrustning in 2002 is:-

Capacity	purchased cost
100	4000$
10	3000$
46	X

After interpolating cost in 2002= 3,400$

$C_{2020} = C_{2002}$*(cost index in 2020/cost index in 2002)

C_{2020} = 3,400$* (160/106)

Centrifugal pump cost = 5,134$= 196,118.89ETB

iii. Pump three: - from dearator to boiler which has the same capacity with the second pump so that cost in 2020 is 5,134$= 196,118.89ETB.

Notice: - All pumps are centrifugal pumps which constructed from carbon steel while, each pumps were required one pump as a reserve. Therefore, the total purchased cost for centrifugal pump is the sum of each pump. So that;

=2[194,157.612+200,234.85+178,429.46+197,560.85+180,095.894+208,301.238+196,118.89+196,118.89ETB = 1,551,017.68ETB

J. Cost of belt conveyor

Cost of belt conveyor to digester:

The length of a belt conveyor is 2.5m and the width of a belt conveyor is 0.83m and approximated to 1m. From table of 6.2, Coulson and Richardson, vol.6

Size= 2.5mSize range= 2-40

Cost in $= 2900 Index= 0.75

The purchased cost of a belt conveyor that transported to the digester process in mid-2004:

$C_e = CS^n = 2900\$*(2.5)^{0.75}$

=5,765.71$

The cost in 2020 = Cost in 2004*(Cost index in 2020/Cost index in 2004)

= 5,765.71 $*(176/112)

= 9,060.4$*(38.2 ETB/$) = <u>346,107.33ETB</u>

Cost of belt conveyor from the washer to dryer:

The width of a belt conveyor is 0.75m and approximate to 1m wide. From table 6.2

Size =2.249mCost = 2900$

Size range = 2-40 Index = 0.75

Purchased equipment cost of water tank in 2004G.C is:

$Ce = CS^n = 2900\$*(2.249)^{0.75} = 5{,}325.86\$$

The purchased cost of belt conveyor in 2020 = cost in 2004*(cost index 2020/cost index 2004)

= 5,325.86$*(176/112)

= 8,369.209$ = <u>319,703.77ETB</u>

K. 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 table 6.2

Size =2m Cost = 2900$

Size range = 2-40 Index = 0.75

Purchased equipment cost of a belt conveyor in mid 2004G.C is

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

The purchased cost of belt conveyor in 2020 = cost in 2004*(cost index 2020/cost index 2004)

= 4,877.2$*(176/112)

= 7,664.171$

= <u>292,771.35ETB</u>

Notice: each belt conveyor was required one reserve belt conveyor.

Therefore, the total purchased cost of belt conveyor needs one reservoir conveyor.

= 2[346,107.33+319,703.77+292,771.35] = <u>958,582.45ETB</u>

Hence, the total purchased equipment cost is the sum of purchased equipment cost of each unit operation, each pump and each belt conveyor.

= 29,682,758.849 + 1,551,017.68 + 958,582.45 = <u>32,192,358.979ETB</u>

Table 6.1.Purchased cost of each equipment

Equipments	No. equipments	Purchased cost(ETB)
Mixer	1	987,738.928
Water storage tank	2	12,505,030.73
Digester	2	3,012,878.312
Diffuser washer	1	484,548.702
Dryer	1	1,104,182.842
Surplus tank	1	3,576,718.198
Detractor	1	3,632,603.77
Boiler	1	4,379,057.372
Belt conveyor	3	958,582.45
Pump	16	1,551,017.68
Total		32,192,358.979

6.2. Estimation of total capital investment

Direct cost; material and labor involved in actual installation of complete facility (70-85% of fixed capital investment).

Purchased equipment cost = 15-40% of fixed capital investment. Use 40%FCI

PEC= 40%FCI

FCI = PEC /40% = 32,192,358.979/ 0.4 = 80,480,897.43ETB

Table 6.2.Total Direct Cost

No.	Item	Range	Percentage (%)	Cost(ETB)
1	Purchased equipment cost	15-40	40FCI	32,192,358.97
2	Installation cost	3-20	4FCI	3,219,235.897
3	Instrumentation and control cost	2-8	3FCI	2,414,426.923
4	Piping	3-20	4FCI	3,219,235.897
5	Electrical(installed)	2-10	3FCI	2,414,426.923
6	Building(including service)	3-18	3FCI	2,414,426.923
7	Yard	2-5	2FCI	1,609,617.949
8	Service facility	8-20	8FCI	6,438,471.794
9	Land	1-2	1FCI	804,808.974
Total Direct Cost				54,727,010.25

Indirect cost: expense which are not directly involved with material and labor of actual installation of complete facility (15-30% of fixed capital investment).

Table 6.3. Total indirect cost

No.	Item	Range	Percentage (%)	Cost(ETB)
1	Engineering and supervision	4-21	5FCI	4,024,044.872
2	Construction expenses	4-16	4FCI	3,219,235.897
3	Contractor fee	2-6	3FCI	2,414,426.923
4	Contingency	5-15	7FCI	5,633,662.82
Total indirect cost				15,291,370.51

Fixed cost is the sum of the total direct and indirect cost. Then:

FC = DC+IC

= (54,727,010.25 + 15,291,370.51) ETB

FC= 70,018,380.76ETB is fixed capital investment

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

TCI= FCI +WC……………………….1

But, working capital is (10-20%) of the total capital investment. We use; WC = 15%TCI

WC = 0.15TCI……………………….2

Substituting into equation (1)

TCI =FCI +0.15TCI

TCI-0.15TCI = FCI

0.85TCI = FCI

TCI= FCI/0.85 = 70,018,380.76 ETB/0.85

TCI = 82,374,565.6 ETB Then,

WC =0.15TCI = 0.15*82,374,565.6 ETB

WC = 12,356,184.84 ETB

6.3. Estimation of total product cost

Total Product Cost = Manufacturing Cost + General Expense

1) Manufacturing Cost

i) Fixed Charges (FC)

a) Depreciation: is 10% of fixed capital investment for machinery and equipments and 2-3 % of building value of fixed capital investment.

D_P = (10%FCI +2%FCI)

= (0.1*70,018,380.76+0.02*70, 018380.76) ETB

D_P = 8,402,205.691ETB

Then, the salvage value calculated from:

$D_P = (V\text{-}VS)/n$,

$V_S = V\text{-}D_P*n$,

Where n is the project life i.e. n =9 years, Vs = TCI = 82,374,565.6 ETB

V_S = 82,374,565.6 ETB – 8,402,205.691ETB*9

V_S = 6,754,713.79 ETB

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

=1% FCI was taken,

= 0.01*70,018,380.76 ETB

=700,183.81ETB

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

= 0.5% FCI

= 0.005*70,018,380.76ETB

= 350,091.9 ETB

d) Rent (8-12% of the value of rented land and buildings), use 8% rented land and buildings.

= 0.08*3,219,235.897 ETB = 257,538.87 ETB

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

FC =D_P +LT+INSU + R

= (8,402,205.691 + 700,183.81+ 350,091.9 + 257,538.87) ETB

FC= 9,710,020.271 ETB

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

Fixed Charges = 10-20% of Total Product Cost; Use FC = 10%*TPC, then:

FC = 0.1*TPC

TPC = FC/0.1= 9,710,020.271 ETB /0.1

TPC = 97,100,,202.71 ETB

2) Direct production costs (about 60% of total product cost)

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

=25% of Total Product Cost

= 0.25*97,100,202.71 ETB = 24,275,050.68 E

ii. Operating labor (10-20% of Total Product Cost)

=15% of Total Product Cost is taken

= 0.15*97,100,202.71 ETB = 14,565,030.41 ETB

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

= 20% of Total Product Cost

= 0.2*97,100,202.71ETB= 19,420,040.54 ETB

iv. Maintenance and Repairs (2-10% of Fixed Capital Investment)

=10% of FCI

= 0.1*70,018,380.76 ETB = 7,001,838.1ETB

Direct production cost is the sum of the:

DPC = RMC +OPC +UC+MRC

= (24,275,050.68 + 14,565,030.41 + 19,420,040.54+7,001,838.1) ETB

DPC = 65,261,959.73 ETB

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

= 0.15*TPC

= 0.15*97,100,202.71= 14,565,030.11 ETB

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

M_C = DPC +FC +POHC

= (65,261,959.73+ 9,710,020.271 + 14,565,030.11) ETB

= 89,537,010.11 ETB

4) General Expenses

i) Administrative costs (about 15% of cost for operating labor, supervision and maintenance or 2-6% of Total Production Cost), use 6% of Total Product Cost

= 0.06*TPC

= 0.06*97,100,202.71 ETB

= 5,826,012.163 ETB

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

= 20% of Total Product Cost

= 0.2*TPC

= 0.2*97,100,202.71ETB = 19,420,040.54 ETB

iii) Research and development cost (about 5% of total product cost), use 5% of total product cost.

=0.05*TPC

= 0.05*97,100,202.71ETB

= 4,855,010.136 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

= (5,826,012.163 + 19,420,040.54 + 4,855,010.136) ETB

= 30,101,062.84 ETB

Then, the Total Product Cost is the sum of the manufacturing cost and general expense.

TPC = MC+GE

= (89,537,010.11 + 30,101,062.84) ETB

= 119,638,072.9 ETB

Table 6.4. Total capital investment and total product cost

Parameters	Estimated cost (ETB)
Direct cost	54,727010.25
Indirect cost	15,291,370.51
Fixed cost	70,018,380.76
Working capital	12,356,184.84
Total capital investment	82,374,565.6
Direct product cost	65,261,959.73
Plant overhead cost	14,565,030.11
Manufacturing cost	89,537,010.11
General expenses	30,101,062.84
Total product cost	119,638,072.9

6.4. Profitability analysis

The profit analysis of the plant is includes gross profit, net profit, payback period, rate on investment, annual cash flow and net present worth.

Gross earning cost

G_{EC} = Total Income - Total Product Cost

Basic information for economic analysis

We have 300 working days per year

Selling price is 800$/ton

The production capacity is 20ton/day

Total Income = capacity*selling price

= 20ton/day*300 day/year*800$/ton*38.2ETB/$

= 183,360,000ETB/year

By taking a base of 1 year, the total income is:

Total Income = 183,360,000 ETB

- Gross earning cost = (183,360,000 – 119,638,072.9) ETB

  = 63,721,927.1ETB

The Net gross earning cost can be calculated as;

$N_{GEC} = G_{EC}$*(1-Income tax)

In most area of Ethiopia the income tax is taken as 0.35 to the official government. Then,

N_{GEC} = 63,721,927.1 ETB*(1-0.35)

= 41,419,252.62ETB

Payback period

First, we calculate the payback reference (P_{Bref}) in order to know the project is feasible or not feasible.

P_{Bref} = (FCI/TCI/I) + (FCI/TCI/n)

But, the life of the project is 9 years and Take the minimum acceptable rate (i) =20%.

= (70,018,380.76/82,374,565.6/0.2)+(70,018,380.76/82,374,565.6/9)

P_{Bref} = 0.85/0.2 + (0.85/9) = 4.34 = 5years

The payback period of the project will be:

P_{BP} = FCI/(N_{GEC}+D_P)

P_{BP} = 70,018,380.76/ (41,419,252.62 + 8,402,205.691)

= 1.4 years

Since, the payback period of the project is less than the payback period of reference, hence the project is feasible.

Breakeven point (volume)

Breakeven point is the production volume at which there is no loss or profit. At this point, any revenue obtained will be sufficient to cover only the fixed capital investment. It can be calculated as follow:

B_{EV} (Q) = Total Product Cost/Selling price

= 119,638,072.9ETB/year/800$/ton*38.2 ETB/$

= 5,712,717.981ton/year

Rate of Return (ROI)

ROI is a performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. ROI measures the amount of return on an investment relative to the investment‟s cost. To calculate ROI, the benefit (or return) of an investment is divided by the cost of the investment.

$$\text{Rate of return (ROR)} = \frac{NGEC}{\text{TCI}} * 100\%$$

= (41,419,252.62ETB/82,374,565.6ETB)*100% = 50.28%

Cash Flow (CF)

CF = Net Gross Earning Cost + Depreciation

= 41,419,252.62ETB/year + 8,402,205.691ETB/yeaR = 49,821,458.31ETB/year

Net Present value (NPV)

Net present value = Annual Present value – Total Capital Investment

$$Annual\ present\ worth\ (PV) = \frac{CF(1+i)^{n-1}}{i(i+1)}$$

$$PV = \frac{49{,}821{,}458.31(1+0.15)^{9-1}}{0.15(0.15+1)} = 883{,}507{,}130.5ETB/year$$

$$NPV = PV - TCI = 883{,}507{,}130.5 - 82{,}374{,}565.6, = 801{,}132{,}564.9ETB/year$$

Profitability index (PI)

$$PI = \frac{NPV}{TCI} = \frac{801{,}132{,}564.9}{82{,}374{,}565.6} = 9.72$$

Since the PI >1, our project is feasible and acceptable.

Cummulative cash flow

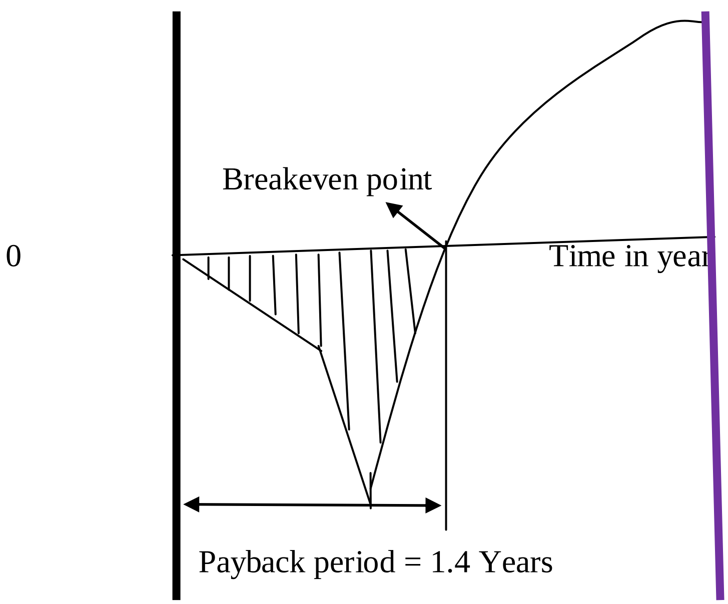


Figure 6.1 Cash flow diagrams

Table 6.5 Man power requirement and labor cost

Sr. No.	Manpower(profession)	Required number	Monthly salary(ETB)	Annual salary(ETB)
1	General manager	1	15,000	180,000
2	Administrative head	1	10,000	120,000
3	Finance head	1	8,500	102,000
4	Accountant	3	6,000	72,000
5	Secretary	5	9,000	108,000
6	Sales men	3	8,000	96,000
7	Purchasing	2	6,000	72,000
8	Production head	2	12,000	144,000
9	Supervision	2	8,000	96,000
10	Operators	15	30,000	360,000
11	Laborer	25	45,000	5,400,000
12	Driver	4	15,000	180,000
13	Security guard	18	40,000	480,000
	Sub-total	98	212,500	7,410,000
	Benefit (10%)	-	21,250	741,000
	Total	98	233,750	8,151,000

CHAPTER SEVEN

7. CONCLUSION AND RECOMMENDATION

7.1 Conclusion

The results obtained from this study have shown that pineapple leaf is suitable non wood raw materials for pulp production. The study shows the suitability of agro wastes materials are able to use as alternative to wood source for pulp making in order to protect and conserve our environment from deforestation with its attendant effects. Pineapple leaf is a highly potential substitute in pulp and paper production because of its high content of cellulose and low lignin content. The factors which affect the production of pulp were cooking time, temperature and concentration of NaOH and Na_2S. Soda pulping processes requires only one chemical (NaOH), but the process uses in large amounts NaOH concentration to effectively break the lignin bonds. Kraft process requires fewer amounts of different chemicals (NaOH and Na_2S) and the process can help to the complete lignin molecule breakage in a small concentration of chemicals. From this it can concluded that Kraft process is more advantageous than soda pulping process.

7.2 Recommendations

- During this project we have faced a lot of challenges that affects our laboratory results like there was insufficient laboratory equipment's, Chemicals, and a problem with shortage of time to do this project laboratory experiment. By this problem some results written by according to literature review. So we recommend that there should be appropriate and sufficient equipment's and chemicals to do laboratory experiments. And there must be enough time present to do Laboratory experiment.
- During pulp production process is environmentally unfriendly by product and gas emission. So its recommend that anyone to do this project it need great attention on the byproduct recovery of pulp production plant.
- This project can be an initial idea to do further detailed researches related to pulp production works. So, to apply the project on ground and establishing pulp producing factories in our country, 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.

REFERENCES

/Ass.,]. E. (n.d.). The Ethiopian Cotton Production progress.

/Ass., E. G. (n.d.). The Ethiopian Cotton Production progress.

]. L. Read. (1995). Fiber supply outlook for North America.

A., S. G. (1992). Handbook for pulp and paper technologists.

A.B., B. H. (1949). Ion exchange in waste treatment. 41: 448-452.

al., R. e. (2002,2007). Comparison of non-wood and wood resources for pulp and paper-making.

Bajpai, P. (2012). Biotechnology for Pulp and Paper Processing.

Ban-Koffi, L. a. (1990). Alcohol production from pineapple waste. . World Journal of Microbiology and Biotechnology, 6:281-284.

Behoer H.L. and Mindler A.B. (1994). Ion exchange in waste treatment. Industrial and Engineering Chemistry, 41, 448-452.

Beoher H.L. and Mindler A.B. (n.d.). Ion exchange in waste treatment.

Calculation for design of a HRSG at Aalborg Engineering. (n.d.).

Co.KGaA., W. V. (2006). Hand book of pulp.

Ethiopia, C. s. (2013). imported commodities report.

FAO . (2016). Food and Agriculture Organization of the United Nations.

FAO. (2015). Banana Market Review.

G., A. R. (2007). Semi-continuous co-digestion of solid slaughterhouse waste, manure and frut and vegetable waste.

Healy, S. &. (2011). Product Classification and its implications on competitiveness and carbon leakage.

Jiménez L., S. L. (2009). Soda-anthraquinone pulping of palm oil empty fruit bunches and beating of the resulting pulp.

Kamoga Omar Lwako M., Byaruhanga Joseph K., and Kirabira John Baptist ;. (2013). “AReview on Pulp Manufacture from Non Wood Plant Materials.

Kissinger S., G. G. (2007). Wood and non-wood pulp production comparative ecological foot printing on the Canadian praireies.

Leena Paavilainen. (1998). European prospects for using non-wood fibers.

McClosekey, J. T. (1995). What about Non wood?

Mona Ali, M. B. (2001). SODA-AQ PULPING OF COTTON STALKS.

Nations), F. (. (2016). Banana Market Review .

Nunes M.C.N., E. J. (2009). Environmental conditions encountered during typical consumer retail display affect fruit and vegetable quality and waste.

Oluwadare, A. O. (2007). The Relationship Between Fibre Characteristics and Pulp-sheet Properties of Leucaena leucocephala (Lam.).

Omar Lwako M., B. J. (n.d.).

Paavilainen, L. (1998). European prospects for using non-wood fibers. PPI (PULP & PAPER INTERNATIONAL) MAGAZINE.

Paavilainen, L. (1998). European prospects for using non-wood fibers.

Read, L. (1995). “Fiber supply outlook for North America.

Santos, R. B.-M. (2012). Kinetics of hardwood carbohydrate degradation during kraft pulp cooking.

Schieber A., S. F. (2001). Bproducts of plant food processing as a source of functional compounds-recent developments.

Sjostrom, E. (1993). Wood Chemistry Fundamentals and Applications.

Smook, 1982; Khristova *et al*, 2004; Vasconcelos, 2005; Sixta, 2006; Khiari *et al*, 2009; Rodríguez *et al*, 2010

Tanaka K., H. Z. (1999). Investigation of the utility of pineapple juice and pineapple waste material as low cost substrate for ethanol fermentation by Zymomonasmobilis. Journal of Bioscience and Bioengineering, 87:642-646.

Tappi. (1985). Freeness of pulp.

Wiley VchVerlagGmbhand Co.KGaA, W. (2006). Hand book of pulp.

Worrell, E. L. (2007). World Best Practice Energy Intensity Values for Selected Industrial Sectors.

Yogesh M1, H. R. (2015). Study on Pineapple Leaves Fibre and its Polymer based Composite. International Journal of Science and Research (IJSR).

APPENDICES

Appendix A: Supporting pictures during laboratory work

Figure1Raw material collectted,washing, cutting and drying

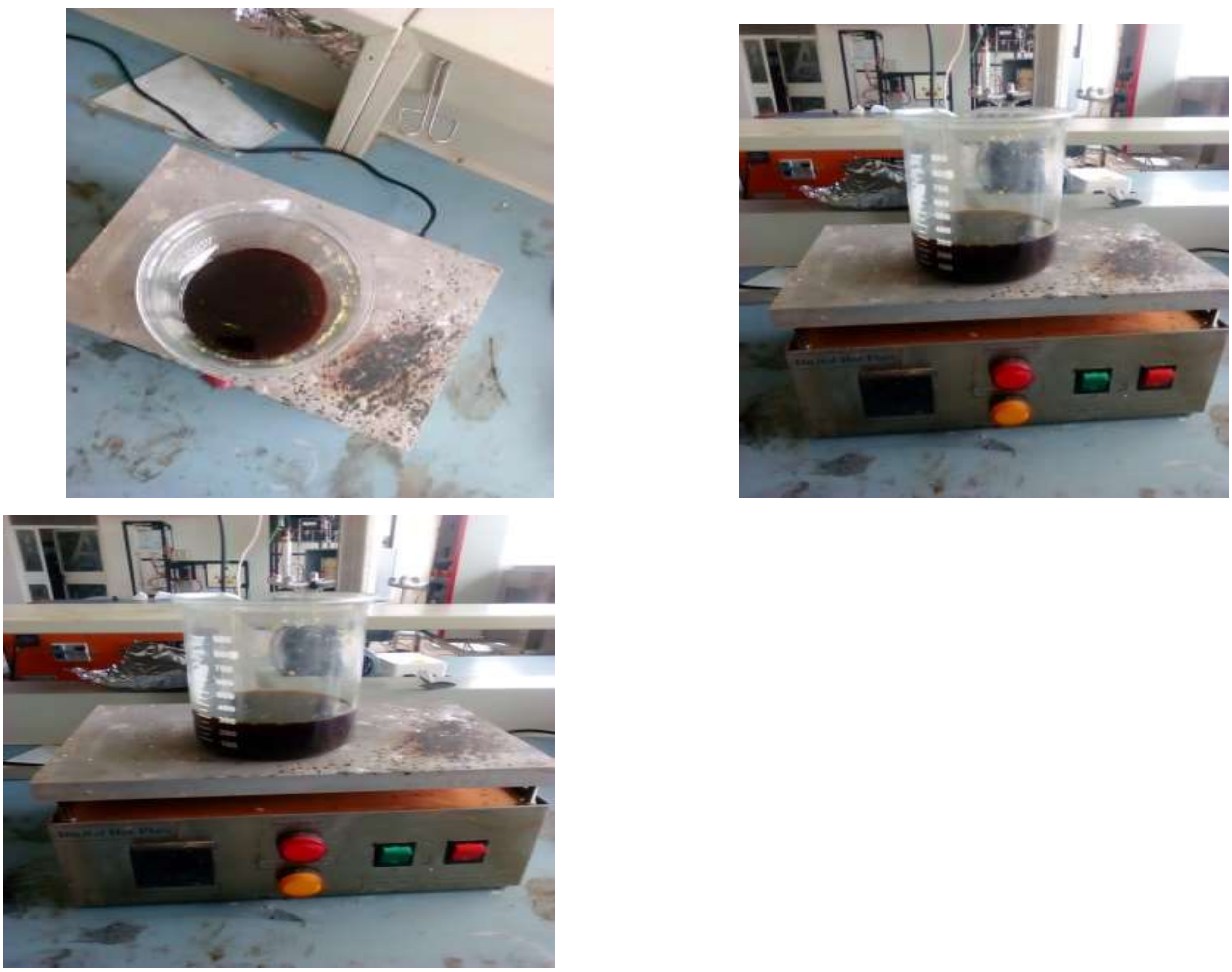


Figure 2 mixing and digestting of pulp

Figure 3 washing,beating and bleaching of pulp

Figure 4 drying, dried pulp and sample of black liquor