WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

FINAL PROJECT ON:

ETHANOL PREPARATION FROM SUGARCANE BAGASSE

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A THESIS SUBMITTED TO WOLKITE UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR SCIENCE (BSc) IN CHEMICAL ENGINEERING (PROCESS STREAM)

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WOLKITE, ETHIOPIA

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DECLARATION

This project done by Feye Berhanu, Kebebe Regane, Teferi Abera, Temesgen Fayera, and Yosef Mengistu and, we are fifth year chemical engineering student. We undersigned and declare that this final project is our original work and compiled according to the department of chemical engineering.

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ABSTRACT

Development of liquid biofuels has entered a new phase of large scale pilot demonstrations. A number of plants in operation or under construction face the engineering challenges of creating a viable plant design, scaling up, and optimizing various unit operations. Energy has become one of the major concerns for our world, the world intention in replacing the non-renewable energy by renewable has become very crucial in terms of reducing negative environmental impact. Bagasse is a by-product disposed from sugar factory in massive quantity, the dried bagasse has a content of cellulose and hemicellulose, which is a high potential in production of fuel ethanol by fermenting the hydrolysed substrate. This thesis aims at utilizing sugarcane bagasse for the production of ethanol by using the yeast Saccharomyces cerevisiae, thus, producing a valuable product from bagasse. Three laboratory experiment was conducted with three difference concentration of acid hydrolysis.94.6g of bagasse is take as sample, mixed with hot water for mixing, and hydrolyzed to break down the cellulose into simple sugar, the PH adjusted to make fever able condition for yeast, yeast media preparation was done for fermentation then mixing the resulting substrate, the media was kept for 24hr under anaerobic condition for alcoholic fermentation, following fermentation the cell mass was separated by filtration, finally the fermented result was distilled to concentrate the ethanol produced, therefore the experiment shows from 94.6g of dried bagasse there obtain 12 ml of hydrous ethanol. During experiment, moisture content and sieve analysis was conducted for the raw material and different analytical and measured data was analyzed like, PH, density and odors were studied. Material balance, energy balance and sizing were conducted in industrial based from annual production rate of $2.74*10^6$L per year. The economic analysis was evaluated that shows with total capital investment of $2,255,154.4, the payback period is 3 years, rate on return on investment is 18% and net present worth is $291,586.3(the value is positive). Therefore, according to the profitability indicator test the project is acceptable and feasible.

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LIST OF ACRONYMS

CO	Carbon monoxide
CO_2	Carbon dioxide
DC	Direct Cost
D	Distillate Flow rate
FCI	Fixed Capital Investment
GHG	Green House Gas
MTBE	Methyl Tertiary Butyl Ether
IDC	Indirect Cost
IRR	Internal Rate of Return
NPV	Net Present Value
NO_x	Nitrogen Oxides
PAN	Proxy Acetyl Nitrate
PBP	Payback Period
PH	Power of Hydrogen
PM	Particulate Matter
ROR	Rate of Return
TCI	Total Capital Investment
TDC	Total Direct Cost
TPC	Total Production Cost
U.S	United State
VOC_s	Volatile Organic Compounds
WC	Working Capital

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CHAPTER ONE

1. INTRODUCTION

1.1 Background

The preparation of ethanol from lignocelluloses biomass has received considerable attention because of the potential of producing large quantities of ethanol for use as a transportation fuel. Bio-fuel has been a source of energy that human beings have since ancient times. Increasing the use of bio-fuels for energy generation purposes is of particular interest nowadays because they allow mitigation of greenhouse gases, provide means of energy independence and may even offer new employment possibilities. Bio-fuels are being investigated as potential substitutes for current high pollutant fuels obtained from conventional sources. About 40% of the total energy consumption is dedicated to transports and in practice requires liquid fuels such as gasoline, diesel fuel, or kerosene. These fuels are all obtained by refining petroleum. This dependency on oil has two major drawbacks: burning fossil fuels such as oil contributes to global warming and importing oil creates a dependency on oil producing countries. Therefore, there is a great interest in exploring alternative energy sources. Unlike fossil fuels, ethanol is a renewable energy source produced through fermentation of sugars (Long,et al.,2014).

Ethanol is widely used as a partial gasoline replacement in the US. Fuel ethanol that is produced from corn has been used in gasohol or oxygenated fuels since the 1980s. These gasoline fuels contain up to 10% ethanol by volume. As a result, the US transportation sector now consumes about 4540 million liters of ethanol annually, about1% of the total consumption of gasoline. Recently, US automobile manufacturers have announced plans to produce significant numbers of flexible-fueled vehicles that can use an ethanol blend (85% ethanol and 15% gasoline by volume) alone or in combination with gasoline. Using ethanol-blended fuel for automobiles can significantly reduce petroleum use and exhaust greenhouse gas emission. However the cost of ethanol as an energy source is relatively high compared to fossil fuels. Ethanol is used for production of alcoholic beverages, for industrial purposes (as solvent, disinfectant or chemical feedstock) and in recent years as a blending agent with gasoline to increase octane and reduce carbon monoxide and other

smog causing emissions. Currently, bagasse is already available at plant site, and production technology of ethanol from sugarcane bagasse may share part of the infrastructure where conventional ethanol is produced, such as pretreatment, hydrolysis, fermentation and distillation units (Cellulosic wkp.retr.,2012).

1.2 Statement of the Problem

The issue of energy security resulting from the depletion of world petroleum reserves, increase of petroleum price and environmental concerns has stimulated governments and researchers to look for alternative renewable energy sources that are technically feasible, economically competitive and environmental friendly. Among alternative energy sources, biofuel derived from biomass, have been gaining increasing attention recently as a replacement for fossil fuels, hence Ethanol is an important biofuel which can be produced from different types of biomass and used for different purpose. Now a days, the numbers of Sugar industries are increasing in Ethiopia and they generate a high amount of sugarcane bagasse. This by-product is mainly used as a low value cattle feed or simply deposited as a waste into land fill. Beside this, sugarcane bagasse remains from animal feed also creates bad odor on the environment which in turn affects health of people who live around the area, so that conversion of such waste into biofuel helps to reduce environmental pollution and energy problem of developing country like Ethiopia.

The commercial production of fuel ethanol in the world relies mainly on the fermentation of sugar and starch, but production of ethanol from such “first generation” feedstock is often viewed as competing with food production and increasing prices of food. So that preparations of ethanol or biofuel from agricultural wastes such as sugarcane bagasse negotiate the debate of food versus energy controversy. Therefore this study was intended to solve such type of problem, to convert this low valuable by product into highly valuable product. The use of ethanol would result in less polluting carbon monoxide and the need of toxic compounds to enhance automotive fuel octane levels. The potential for global warming would decrease because of lower hydrocarbon emission in the air. Less dependency on foreign ethanol to satisfy our country consumption needs would increase energy and economic feasibility.

1.3 Objectives

1.3.1 General objective

The main objective of this thesis project was the preparation of ethanol from sugarcane bagasse.

1.3.2 Specific objectives

- To evaluate preparation of ethanol from different amount of grinded bagasse.
- To analysis efficiency of ethanol through experiment at different concentration of dilute sulfuric acid at the stages of pretreatment, hydrolysis, fermentation and distillation.
- To perform the basic material and energy balance on specific unit operation.
- To determine the feasibility aspects of ethanol preparation from bagasse.

1.4 Significance of the Project

This project may have a great significance in terms of ethanol preparation from sugarcane bagasse was economically and environmental advantages for the country. Because of their economic feasibility analysis shows that the ethanol obtained from bagasse cheaper than molasses. So, bagasse is compatible for this reason. Some of these advantages are: to satisfy the demand of population, to create job opportunity for employers, to decrease foreign currency and dependency. Likewise, contributes to develop understanding on long-term ethanol production and transport fuel substitution shifts in Ethiopia and thus provides a significant role to academic researchers, business societies, industrialists, policy makers, and all interested groups.

1.5 Scope of the Study

In order to achieve the stated objective, the following scopes of study have been identified:

- To study the effect of different concentration of dilute sulfuric acid on pH of ethanol product.
- To study the effect of different concentration of dilute sulfuric acid on density of ethanol product.
- To study effect of different concentration of dilute sulfuric acid on preparation of ethanol.

CHAPTER TWO

2. LITERATURE REVIEW

This chapter consist of two sections, the first section presents background information on ethanol, sugarcane bagasse, feed-stocks for ethanol preparation, ethanol preparation process, parameters affect hydrolysis and fermentation, and the second part discusses global and local trends on ethanol production.

2.1 Ethanol

The use of ethanol as an automobile fuel is not a new invention. Already in 1908, Ford's model T could be adjusted to run on either gasoline or alcohol (DiPardo, 2000). However, after World War II the interest in using ethanol as a fuel declined because cheap gasoline made from petroleum was available. In 1970's, the interest in fuel ethanol was renewed due to the oil crisis (DiPardo, 2000). More recently, ethanol has become used as an additive in gasoline. MTBE (methyl tertiary butyl ether) is used as a gasoline additive to increase the oxygen content and the octane number. During the last few years, the use of MTBE has been banned in several states of USA due to the risk of contamination of water. Many companies have replaced MTBE with ethanol to give the gasoline similar clean burning and octane boosting properties as MTBE-blended gasoline (Sun and Cheng, 2002). Today, there are several flexi fuel automobile models (vehicles that can run on mixtures of ethanol and gasoline containing up to 85% ethanol) available from various manufacturers (BAFF, 2006).

About 99% of the fuel ethanol is produced from cultivated crops (BAFF, 2006). Brazil has for a long time been the leading ethanol producer of the world. However, during the last few years USA has increased its production and in 2012 both countries have an annual production of about 16 million m^3 (Berg., F. O. Licht, 2001). The Brazilian ethanol is mainly produced from sugarcane. Brazil is the world leader in the use of ethanol as an automobile fuel. In Brazil, the ordinary gasoline, which is used in about 7,000,000 cars, contains about 24% ethanol. In addition, 4 million automobiles drive on a blend of 95% ethanol and 5% water (BAFF, 2006). In USA, ethanol is mainly produced from corn.

In Sweden, about 55,000 m^3 of fuel ethanol is produced per year from wheat and about 18,000 m^3 from spent sulfite liquor (Agroetanol AB, 2006; Jordbruksverket, 2006). In Sweden, the ordinary gasoline typically contains 5% ethanol and the number of flexi fuel automobiles is increasing (Jordbruksverket, 2006). The Swedish ethanol production does not cover the demand and therefore Sweden is a net importer of ethanol. However, initiatives have been taken to increase the future national ethanol production. In 2004 ethanol from lignocellulose pilot plant was inaugurated in the city of Örnsköldsvik (Sweden). Ethanol plans to expand its production of ethanol from lignocellulose biomass with 150,000 m^3 in 2008.

2.2 Sugarcane

Sugarcane is a grass which contains approximately 70% water, 20% biomass, and 10% sugar. Biomass approximately contains 55% cellulose, 25% hemicellulose, and 18% lignin on percent dry basis (Nirbhay,2008).

Properties of sugarcane

Sugar consists mainly of sucrose and to a certain extent of glucose and fructose. Thus properties of sugars are listed below:

Table 1: Physical properties

Taste	Sweet
Crystal	Monoclinic
Specific gravity at 20 ^{0}C	1.05917
Optical activity	Dextro-rotatory

Table 2: Chemical properties

Action of heat	Perfectly dry sugar can be heated to 160^{o}C without decomposition. It then melts forming a non-crystallizing substance. In the presence

	of moisture it decomposes at 100°C, becoming a caramel and liberating water. On further heating changes to Co_2 and formic acid.
Action of heat on dilute solutions	By prolonged heating at the boiling point the dissolved sucrose slowly combines with water and breaks up into glucose and fructose.

2.3 Sugarcane Bagasse

Sugarcane bagasse is the solid residue obtained after extraction of the juice from sugar cane and can be a potential substrate for ethanol production. Bagasse is a lignocellulose material. Cellulosic resources are in general very widespread and abundant. For example, forests comprise about 80% of the world's biomass. Being abundant and outside the human food chain makes cellulosic materials relatively inexpensive feed stocks for ethanol production. The term hemicellulose is often used to describe the total carbohydrate contained in a plant or microbial cell. The composition of lignocelluloses varies greatly among the major categories of plant sources (i.e. softwoods, hardwoods, straws) and also varies within each category. In spite of these differences, the major components of all lignocelluloses are cellulose, hemicellulose, lignin and extraneous materials

Table 3: Chemical composition of bagasse

Composition	Contents (%)
Cellulose	50
Hemicellulose	22.5
Lignin	21
Ash	2.5
Waxes	Less than 1

2.4 Review on Ethanol

Ethanol is a clean burning renewable resource that can be produced from fermented cellulosic biomass. It is produced from different lignocelluloses materials basically the agro wastes like sugarcane bagasse, rice husk, wheat straw, corn fiber, crop residues, grasses and other materials like saw dust, wood chips, solid animal wastes etc. But in our project sugarcane bagasse was selected as raw material (Nirbhay,2008).

Physical Properties

Ethyl alcohol under ordinary condition is volatile, flammable, clear, colorless liquid. The boiling point of ethanol (ethyl alcohol) is 78.4^0c (Nirbhay,2008). Its odor is pleasant, familiar and characteristics as is its taste when suitable diluted with water. Otherwise its taste may be pungent. The physical and chemical properties of ethyl alcohol are primarily dependent upon hydroxyl group. This group imparts polarity to the molecule and also gives rise to hydrogen bonding. These two properties account for the abnormal physical behavior of lower molecular weight alcohols as compared to hydrocarbons of equivalent weight. Infra-red spectrographic studies have shown that, in the liquid state, hydrogen bonds are formed by the attraction of the hydroxyl hydrogen of one molecule and the hydroxyl oxygen of a second molecule. The net effect of this bonding is to make liquid alcohol behave as though it were largely dimer zed. This behavior is analogous to the behavior of water, which however is more strongly bonded and appears to exist in liquid clusters of more than two molecules. The association of ethyl alcohol, it should be noted, is confined to the liquid state in the vapor state, this alcohol is monotheric.

The molecular association of liquid ethyl alcohol gives rise to an abnormally high boiling point and a high heat of vaporization (Process bio.et al., 2002). Ethyl alcohol's polarity and association also manifest themselves in the non-ideal behavior of many ethyl alcohol solutions and in the fact that ethyl alcohol forms a large number of azeotropes. Many other examples of ethyl alcohol abnormalities may be found in the properties of ethyl alcohol solutions appearing in the literature (Nirbhay,2008).

Chemical Properties

The chemical properties of ethyl alcohol are primarily concerned with the hydroxyl group, namely reactions involving dehydration, dehydrogenation, oxidation and esterification. The H_2 atom of the hydroxyl group can be replaced by an active metal, such as sodium, potassium and calcium with the formation of a metalethoxide (ethylate) and the evolution of H_2 gas.

$$2C_2H_5OH + 2M \longrightarrow 2C_2H_5OM + H_2$$

Sodium ethoxide can be prepared by the reaction between absolute ethyl alcohol and sodium or by refluxing absolute ethyl alcohol with anhydrous sodium hydroxide, as shown

$$CH_3CH_2OH + NaOHCH_3 \longrightarrow CH_2ONa + H_2O$$

The sodium ethoxide precipitates upon addition of anhydrous acetone. This strong base hydrolyses readily to give ethyl alcohol and sodium and hydroxyl ions

$$CH_3CH_2O^-Na^+ + H_2O \longrightarrow CH_3CH_2OH + Na^+ + OH^-$$

Commercially water is removed by a zeotropic distillation with benzene. Sodium ethoxide may also be prepared by reacting sodium amalgam with ethyl alcohol. Sodium ethoxide is used in organic synthesis as a condensing and reducing agent. The reaction between sodium ethoxide and Sulphur mono chloride results in the formation of diethylthiosulphate

$$2CH_3CH_2ONa + S_2Cl_2 \longrightarrow (CH_3CH_2)_2S_2O_2 + 2NaCl$$ (Process bio.et al., 2002).

2.5 Feed stocks for Ethanol Preparation

Ethanol can be produced synthetically from petroleum or by the microbial fermentation of sugars. The three main groups of raw materials for the production of ethanol by fermentation are sugar, starch, and lignocellulose (Lin and Tanaka, 2006). Sugar-containing raw materials include sugarcane, sugar beets, fruits and sweet sorghum. The advantage with the sugar-based raw materials is that they can be converted into ethanol directly without hydrolysis. A disadvantage is that many of these raw materials are considered to be a human food resource and will therefore be too expensive to use for ethanol production (Badger, 2002).

Starch-based materials that are commonly used for ethanol production include corn, potatoes, cassava, and various cereal grains. Starch is a biopolymer and defined as a homopolymer consisting only one monomer, D-glucose (Pongsawatmanit et al., 2007). During ethanol production from starch, it is necessary to break down the chains of this carbohydrate for obtaining glucose syrup, which can be converted into ethanol by yeasts. This type of feedstock is the most utilized for ethanol production in North America and Europe (Pongsawatmanit et al., 2007). Starch can be converted to fermentable sugar by a method called the hydrolysis technique. Hydrolysis is a reaction of starch with water, typically performed by cooking the starch at high and low temperatures which is normally used to break down the starch into fermentable sugar. Dextrin oligosaccharides are generated by adding α-amylase and glucoamylase to obtain glucose (Wheals et al., 1999). A disadvantage of using starch-based materials for ethanol production is high hydrolysis cost due to high energy costs of the cooking step and the high costs of the amylolytic enzymes (Lin and Tanaka, 2006).

Lignocellulose-based feedstocks that can be considered for ethanol production are wood residues, agricultural residues, and the spent sulfite liquor from pulp and paper mills. The advantage of using lignocellulose as raw material for ethanol production is due to its abundance and relatively cheap (Wheals et al., 1999). In contrast to sugar-containing crops, the utilization of lignocellulose as a substrate for ethanol production is difficult or relatively recalcitrant to hydrolysis (Gray et al., 2006). Because of its complex structure, this resists degradation. The basic structure of all lignocellulosic biomass consists of cellulose $(C_6H_{10}O_5)_X$, hemicelluloses $(C_5H_8O_4)m$, and lignin $[C_9H_{10}O_3.(OCH_3)0.9 - 1.7]n$. Energy-related expenses for planting, fertilization and harvesting can be avoided if waste materials are used. If lignocellulosic waste materials are used, there will not be any competition for the limited agricultural land available, which instead might be needed for food production (Sun and Cheng, 2002).

Lignocellulosic Material as Sources of Ethanol

Lignocelluloses biomass is an organic residue which consists of mainly cellulose, lignin and hemicelluloses, whose basic units are sugars that can be fermented into ethanol or other chemical. These structural materials are produced by plants to form the cell walls, leaves,

stems, stalks, and woody portions of the plant. The carbohydrate polymers (cellulose and hemicelluloses) are tightly bound to the lignin. Up to 80% of the lignocelluloses are polysaccharide (Kaparaju et.al., 2009).Lignocelluloses plant structures also contain a variety of plant-specific chemicals in the matrix, called extractives (resins, phenolic, and other chemicals), and minerals (calcium, magnesium, potassium, and others).

Lignocellulosic biomass comprising forestry, agricultural and agro-industrial wastes are abundant, renewable and inexpensive energy sources. Such wastes include a variety of materials such as sawdust, poplar trees, sugarcane bagasse, waste paper, brewery spent grains, switch grass, straws, stems, stalks, leaves, husks, shells and peels from cereals like rice, wheat, corn, sorghum and barley. Lignocellulose wastes are accumulated every year in large quantities, causing environmental problems. However, due to their chemical composition based on sugars and other compounds of interest, they could be utilized for the production of a number of value added products, such as ethanol, food additives, organic acids, enzymes, and others. Therefore, besides the environmental problems caused by their accumulation in the nature, the non-use of these materials constitutes a loss of potentially valuable sources (Mussatto and Teixeira, 2010). The major constituents of lignocellulose are cellulose, hemicellulose, and lignin, polymers that are closely associated with each other constituting the cellular complex of the vegetal biomass.

Composition of Lignocellulosic material

Cellulose

Cellulose is a polysaccharide of hundreds or thousands of molecules of glucose with the formula $(C_6H_{10}O_5)n$. Cellulose molecules consist of long chains of glucose molecules like starch molecules with a different structural configuration. The structure of cellulose plus the encapsulation of cellulose by lignin in lignocellulosic materials makes cellulosic materials more difficult to hydrolyze than starch polymers (Harinen, 2004).

Hemicelluloses

It is a complex polysaccharide made from a variety of five- and six-carbon sugars. While cellulose is crystalline, strong, and resistant to hydrolysis, hemicellulose has a random, amorphous structure with little strength, as such it is easily hydrolyzed by dilute acid or

hemicellulase enzymes. It consists of several matrix polysaccharides (hetero-polymers), such as arabinoxylans, present a long with cellulose in almost all plant cell wall. Hemicelluloses differ in three ways from cellulose; by presence of shorter chain, branching of the main molecule and composition of several sugar units (Harinen, 2004).

Table 4: Differences between cellulose and hemicellulose Cellulose

Cellulose	Hemicellulose
Consists of glucose units	Consists of various units pentose and hexoses
High degree of polymerization	Low degree of polymerization
Forms fibrous arrangement	Do not form fibrous arrangement
Presents crystalline and amorphous regions	Present only amorphous regions
Slowly attacked by diluted inorganic acid in hot conditions	Rapidly attacked by diluted inorganic acid in hot conditions
Insoluble in alkalis	Soluble in alkalis

Lignin

Lignin is a highly complex, three-dimensional polymer of different phenyl propane units, which are bound together by ether and carbon-carbon bonds. It is one of the most abundant and important polymeric organic substance in the plant. Lignin is unusual because of its heterogeneity and lack of a defined primary structure. Few lignin structures have been known, but generally their structures remain unknown. Although there are great numbers of microorganisms, which are able to utilize hemicelluloses and cellulose, relatively few strains have the ability to decompose the lignin effectively (Laser et al., 2002).

Extractives and ash

Any numbers of different compounds (resins, phenolic, and other chemicals) in biomass that are not an integral part of the cellular structure are called extractives. These compounds can be extracted from biomass by means of polar and non-polar solvents including hot or

cold water, ether, benzene, methanol, or other solvents that do not degrade the biomass structure.

Table 5: Main component of lignocellulose wastes (Mussatto and Teixeira, 2010)

Lignocellulosic waste	Cellulose (wt %)	Hemicellulose (wt %)	Lignin (wt %)
Barley straw	33.8	21.9	13.8
Corn cobs	33.7	31.9	6.1
Corn stalks	35.0	16.8	7.0
Rice straw	36.2	19.0	9.9
Sugarcane bagasse	40.0	27.0	10.0
Wheat straw	32.9	24.0	8.9

2.6 Ethanol Preparation process

The major unit processes which involves in the production of ethanol from Lignocellulosic material are pretreatment, hydrolysis, fermentation, and distillation.

2.6.1 Pretreatment

The goal of the pretreatment process is to remove lignin and hemicellulose, reduce the crystallinity of cellulose, and increase the porosity of the lignocellulosic materials. Pretreatment must meet the following requirements: (1) improve the formation of sugars or the ability to subsequently form sugar by hydrolysis, (2) avoid the degradation or loss of carbohydrate,(3) avoid the formation of byproducts that are inhibitory to the subsequent hydrolysis and fermentation processes, and (4) be cost-effective. Pretreatment methods can be roughly divided into different categories: physical (milling and grinding), chemical (alkali, dilute acid, and organic solvents), biological or a combination of these. The above

pretreatment technologies have been promising for cost-effective pretreatment of lignocellulosic biomass for biological conversion to fuels and chemicals.

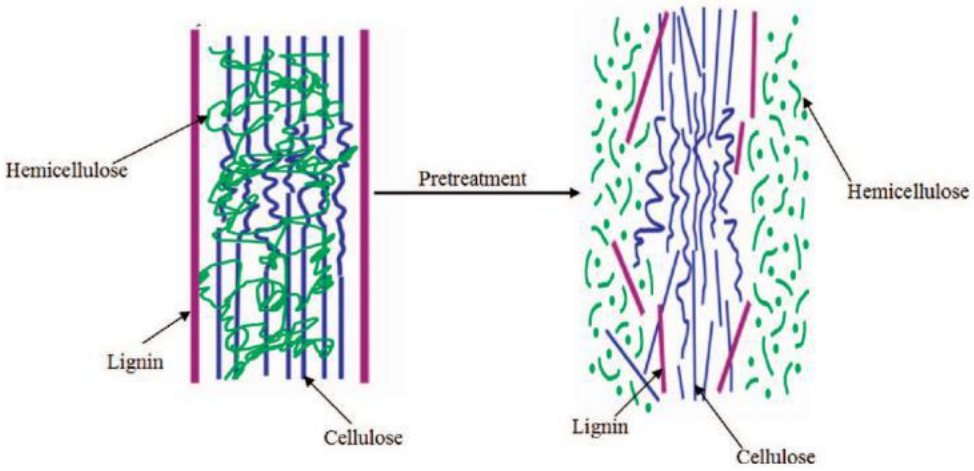


Figure 1: The pretreatment in the conversion of biomass to fuel (Hsu et al.,1980)

Physical pretreatment

Under pretreatment the unnecessary materials is removed by necked eye and the treated raw material that is sugarcane bagasse is put in the oven to reduce the moisture content to facilitate a favorable milling operation and taking the dried sample for grinding. During fermentation the enzymes must be able to get at the bagasse content in order to degrade them. For this, the bagasse must be broken in to smaller pieces. The greater the extent of communition, the larger the surface available for enzymatic attack and the better the breakdown of the lignocellulose material during hydrolysis. In addition to this it aides for faster extraction of soluble components from the bagasse during enzymatic conversion .the milling process can perform in conical crusher, ball mill etc. The size of the grinded materials is below 1mm after milling or grinding. The power requirement of mechanical comminution of agricultural materials depends on the final particle size and the waste biomass characteristics.

Chemical pretreatment

Chemical pretreatment involves the depolymerization of Lignocellulosic materials with chemical agents such as acid, inorganic solvents, alkali and peroxidases.

Alkali Pretreatment

Alkali pretreatment is conducted under milder conditions at lower temperature and pressure compared with acid pretreatment. However, alkali pretreatment is much more time consuming and the reaction time greatly depends on the operation temperature selected (Mosier et al., 2005; Wyman et al., 2005). The major effect of alkali pretreatment is the saponification of intermolecular ester bonds which cross link lignin and carbohydrates, thus increasing porosity and internal surface area of the biomass matrix as well as decreasing the degree of crystallinity of cellulose (Sun and Cheng 2002).

Lignin can also be disrupted and removed from the biomass matrix, resulting in improved susceptibility of the remaining polysaccharides to enzyme attack during hydrolysis. One limitation related to alkali pretreatment is the formation of unrecoverable salts within the biomass feedstock. Bases such as sodium hydroxide, potassium hydroxide, and ammonia can be used for biomass pretreatment. Base solutions cause swelling of biomass, which subsequently leads to decrease in the degree of polymerization, decrease in crystallinity, disruption of the lignin structure, and separation of structural linkages between lignin and carbohydrates. Among the bases investigated, ammonia has the highest potential for use in commercial processes since it can be recovered and recycled due to its high volatility. Thus, it reduces chemical cost and waste treatment cost (Mosier et al., 2005).

Biological treatment

Biological pretreatment employs wood degrading microorganisms, including white, brown, and soft rot fungi, and bacteria to modify the chemical composition and/or structure of the Lignocellulosic biomass so that the modified biomass is more amenable to enzyme digestion. Most biological pretreatment so far has focused on the degradation of lignin in lingo-cellulosic biomass. However, degradation of lignin usually accompanies the loss of cellulose and hemi-cellulose. In order to reduce and eliminate the sugar loss during biological pretreatment, the microbial strains should have low cellulase activity. White rot fungi are the most widely studied for biological pretreatment since they can degrade lignin more effectively and more specifically. Biological pretreatment appears to be a promising technique and has very clear advantages, including no chemical requirement, low energy

input, mild environmental conditions, and an environmentally friendly working manner. However, biological pretreatment is very slow (taking from weeks to a year) and requires careful control of growth conditions and a large amount of space to carry out. In addition, most lignolytic microorganisms solubilize or consume not only lignin but also hemicellulose and cellulose (Mosier et al., 2005).

2.6.2 Hydrolysis

Hydrolysis is a process where carbohydrate polymers are converted to simple fermentable sugars. This is facilitated through the pretreatment process, which changes the structure of the biomass (larger pores and higher surface area), thus allow the enzymes or chemical to enter the fiber (Alfani et al., 2000). Hydrolysis is essential before fermentation to release the fermentable sugars. In the process, cellulose is cleaved to glucose, while hemicellulose results in several pentoses and hexoses (Taherzadeh and Karimi, 2007). The cellulose molecules are composed of long chains of glucose molecules. In the hydrolysis process, these chains are broken down to "free" the sugar, before it is fermented for alcohol production. There are two major hydrolysis processes (Process bio.et al., 2002). Chemical reaction using acids, or an enzymatic reaction. Cellulose and hemicellulos can be converted into ethanol, while lignin remains as a by-product;

Cellulose $\xrightarrow{\text{hydrolysis}}$ Glucose $\xrightarrow{\text{Fermentation}}$ Ethanol

Hemicelluloses $\xrightarrow{\text{hydrolysis}}$ Pentose and Hexose $\xrightarrow{\text{Fermentation}}$ Ethanol.

The hydrolysis step can be performed in different ways, either acidic (dilute and concentrated) or enzymatic hydrolysis (Galbe and Zacchi, 2002).

Diluted acid hydrolysis

Chemical hydrolysis means primarily the use of acids; diluted or concentrated. Due to environmental and corrosion problems, dilute-acid hydrolysis has been prioritized instead of concentrated acid (Balat, 2011). In chemical hydrolysis, the pretreatment and the hydrolysis can be combined. Hydrolysis by dilute-acid occurs under high temperature and pressure with a short residence time, resulting in degradation of hemicellulose and cellulose. However, the glucose yield is low, glucose decomposition occurs and there will

be a formation of high amount of undesirable by-products. The harsh conditions (acid together with high temperature and pressure) lead to high utility costs and the process will also require downstream neutralization (Balat, 2011).

The main drawbacks of dilute acid hydrolysis, especially those performed in batch processes, are sugar degradation during hydrolysis, low overall sugar yield and the formation of several by-products which inhibit the fermenting microorganism (Balat, 2011).The high hydrolysis temperature also causes corrosion problems even at low acid concentration and accelerates the sugar degradation. One way to reduce the sugar degradation is to perform a two-stage dilute acid hydrolysis. Here, mainly hemicellulose is hydrolyzed at relatively mild conditions to recover the 5-carbon sugars while the second stage is conducted under harsh conditions to recover the 6-carbon sugars (Balat, 2011). A stage dilute acid hydrolysis is generally preferred over a one stage hydrolysis, since sugar degradation is reduced and less inhibitor is produced.

Concentrated Acid Hydrolysis

Hydrolysis of cellulosic materials by concentrated sulfuric acids is a relatively old process. The concentrated acid process uses relatively mild temperatures, and the only pressures involved are those created by pumping materials from vessel to vessel. Reaction times are typically much longer than for dilute acid (Demirbas, 2005). This method generally uses concentrated sulfuric acid followed by a dilution with water to dissolve and hydrolyze or convert the substrate into sugar. This process provides a complete and rapid conversion of cellulose to glucose and hemicelluloses to 5-carbon sugars with little degradation. The critical factors needed to make this process economically viable are to optimize sugar recovery and cost effectively recovers the acid for recycling.

The primary advantage of the concentrated acid process is the potential for high sugar recovery efficiency. The acid and sugar are separated via ion exchange and then acid is re-concentrated via multiple effect evaporators. The low temperatures and pressures employed allow the use of relatively low cost materials such as fiberglass tanks and piping. The low temperatures and pressures also minimize the degradation of sugars (Demirbas, 2005). Unfortunately, it is a relatively slow process and cost effective acid recovery

systems have been difficult to develop. Without acid recovery, large quantities of lime must be used to neutralize the acid in the sugar solution. This neutralization forms large quantities of calcium sulfate, which requires disposal and creates additional expense (Demirbas, 2005). In general, acid treatment is effective in solubilizing the hemicellulose component of biomass. Proper combinations of pH, temperature, and reaction time can result in high yields of sugars, primarily xylose from hemicellulose. Sulphuric acid is a catalyst for this reaction and, in this work, was used to study the hydrolysis of sugarcane bagasse hemicellulose. The effects of temperature, acid concentration and time were studied, and the effectiveness of the hydrolysis was evaluated in terms of hemicellulose solubilization (Prasad, S.et al.,2007).

Enzymatic hydrolysis

Enzymatic hydrolysis can occur under milder conditions typically 40-50ºC and pH 4.5 to 5), which give rise to two advantages of the process; low utility cost since there is low corrosion problems and low toxicity of the hydrolyzates (Taherzadeh and Karimi, 2007). In addition, it is also an environmental friendly process (Balat, 2011). However, enzymatic hydrolysis has also disadvantages compared to the dilute-acid hydrolysis; longer hydrolysis time, enzymes are more expensive than acid and end product inhibition can occur (Taherzadeh and Karimi, 2007). Although, many experts consider enzymatic hydrolysis as the most cost-effective process in the long run (Hamelinck et al., 2005) and it is thought to be the key process to achieve an economically viable ethanol production (Horn and Eijsink, 2010). The degradation of cellulose to glucose in enzymatic hydrolysis is catalyzed by specific cellulolytic enzymes; cellulases. This is a group of enzymes with specificity to hydrolyse glycosidic bonds (Howard et al., 2003). Cellulases are naturally produced by microorganisms, mainly bacteria and fungi, which are capable of degrading cellulosic material.

2.6.3 Fermentation

Fermenting microorganisms are used for the conversion of monomeric sugars to ethanol. Different organisms such as bacteria, yeast and fungi can be used for the conversion, however the most frequently used organism in industrial processes are the robust yeast Saccharomyces cerevisiae (baker's yeast). The drawback of Saccharomyces cerevisiae is

not produce ethanol from xylose but Pichia stipitis yeast is produce ethanol from both glucose and xylose sugar, however this type of yeast also has many drawbacks such as low ethanol ,temperature and inhibitor resistance (Galbe and Zacchi 2002).

Baker's yeast (Saccharomyces cerevisiae) is the most commercially used microorganism for ethanol production, but it cannot ferment xylose. They do so to obtain energy and to grow and the fermentation time for the experiment is for ten days and temperature is 35ºC. According to the reactions, the theoretical maximum yield is 0.5 kg ethanol and 0.49 kg carbon dioxide per kg sugar (Taherzadeh and Karimi, 2007).

$$C_6H_{12}O_6 \xrightarrow{\text{yeast}} 2C_2H_5OH+2CO_2$$

$$3C_5H_{10}O_5 \xrightarrow{\text{yeast}} 5C_2H_5OH+5CO_2$$

When the glucose yield is high, Saccharomyces cerevisiae has the ability to produce ethanol also under aerobic conditions (Brandberg, 2005). One drawback is that it cannot ferment pentose's, which are an interest when using Lignocellulosic biomass. Studies have therefore been performed to genetically modify Saccharomyces cerevisiae to become both a pentose and glucose fermenting yeast. Other microorganisms have the ability to ferment pentose's and another way to ferment Lignocellulosic material is therefore to use different yeasts and to separate the two processes; glucose fermentation and pentose fermentation (Galbe and Zacchi, 2002).The efficiency of fermenting process depends on several factors; choice of microorganism, raw material, pretreatment method, hydrolysis method and environmental factors such as pH, temperature, substrate and ethanol concentration. Common conditions for fermentation with Saccharomyces cerevisiae are normally pH 5.0 and a temperature of maximum 35ºC (Alfani et al., 2000).

2.6.4 Distillation

Distillation is one of the steps of the purifications. Distillation is the method used to separate two liquid based on their different boiling points. However, to achieve high purification, several distillations are required. This is because all materials have intermolecular interactions with each other, and two materials will co-distill during distillation. This means that proportion between two materials, in this case ethanol and water can be changed, and still, there are two materials in layers, the liquid and the vapor

layers. Whatever method of preparation is used, the ethanol is initially obtained in a mixture with water. The ethanol is then extracted from this solution by fractional distillation. Although the boiling pion of ethanol is 78.3^{O}c, is significantly lower than the boiling point of water, 100^{0}C, and these materials cannot be separated completely by distillation. Instead, an azeotrope mixture (i.e. a mixture of 95% ethanol and 5% water) is obtained, and the boiling point of the azeotrope is 78.15^{0}C. In a distillation, the most volatile material (i.e. the material that has the lowest boiling point) is the first material to distill from the distillation flask, and this material is the azeotrope of 95% ethanol which has the lowest boiling point. If an efficient fractionating column is used, 95% alcohol could be obtained first and then a small intermediate fraction of lower concentration, and then water. But no matter how efficient the fractionating column used, 95% alcohol cannot be further concentrated by distillation because the vapor has exactly the same composition as the liquid; towards distillation, then, 95% alcohol behaves exactly like a pure compound. Lower boiling components will preferentially vaporize first. This vapor passes into a distilling head and then into a Condenser. Within the Condenser the vapor is cooled and it liquefies. The resulting liquid is then collected in a receiving flask. Initially, low boiling components are collected in the receiving flask. As the distillation proceeds, these components are depleted from the distilling pot and higher boiling components begin to distil over. Switching out the receiving flask at the appropriate point allows for the separation of the component liquids of the mixture. The particular type of distillation used in laboratory is known as Simple distillation. Simple distillation works particularly well on mixtures of two liquids in which the liquids have a very large boiling point difference. The lower boiling component distills off first and can be collected. A downside of simple distillation is that the purity of the distillate is rarely 100%. This is because the distillation vapor is only enriched in the lower boiling component. Some of the higher boiling component will be present as well. So the condensed distillate will be a mixture enriched in the lower boiling component, but still containing some of the higher boiling component. To make matters worse, as the distillation proceeds, the liquid in the distilling pot will have a greater and greater percentage of higher boiling components. Hence, the distillate, over time, wills wind-up containing more, and more of the higher boiling component. Hydrous

ethanol is usually produced through conventional distillation, hydrous ethanol production, containing between 92.8 and 93.5 wt. %ethanol (J.M.L.Coulson,1990).

Dehydration

After distillation, about 5% of water remains in ethanol. Especially, this water is a big problem for fuel ethanol because the presence of this amount of water enhances the molecular polarity of ethanol when it is mixed with gasoline. Consequently, they separate into two phases, ethanol phase and gasoline phase. It is easy to imagine that this in homogeneous fuel is not acceptable. Thus, dehydration can be another issue. For the ethanol to be usable as a fuel, water must be removed. Most of the water is removed by distillation, but the purity is limited to 95-96% due to the formation of a low boiling water-ethanol azeotrope. For blending with gasoline, purity of 99.5 to 99.9% is required, depending on temperature, to avoid separation. Currently, the most widely used purification method is a physical absorption process using molecular sieves and another method is a zeotropic distillation.

Molecular sieves

The molecular sieve is a bed of zeolite that operates in semi-continuous mode. The bed is saturated with water after a period of time and is then regenerated. Hence, there are usually two sieves being operated in parallel one being saturated with water while the other is being regenerated (dehydrated) using air under vacuum. Heat exchanger heats air with an assumed relative humidity of 70% at 20 °C to 95 °C. The air at the outlet of the dehydrating molecular sieve is cooled down to 25 °C in heat exchanger and this stream leaves this exchanger saturated with water at 25 °C (Berg., F. O. Licht, 2001).

2.7 Parameters affecting hydrolysis of Lignocellulosic materials

2.7.1 Properties of the substrate

The properties of the substrate can affect the hydrolysis. These properties are: neutralizing capacity, proportion of easily hydrolysable hemicellulose and cellulose, amount and rate of hydrolysis of the difficult to hydrolyze materials, the length of the macromolecules, degree of polymerization of cellulose, configuration of the cellulose chain, and association

of cellulose with other protective polymeric structures within the plant cell wall such as lignin, pectin, hemicellulose, protein, mineral elements, etc. Particle size is also one of the effective parameters.

2.7.2 The acidity of the system

Another parameter affecting the hydrolysis is the acidity of system. The acidity is dependent on the type and concentration of the acid used, amount of acid solution, amount of acid released from the biomass during hydrolysis, liquid to solid ratio, the neutralizing capacity of the lignocellulose, and movement of the solution during heating. When dilute acid hydrolysis is applied in a continuous process such as a screw fed co-current reactor, it requires a relatively short residence time. Therefore, the penetration of acid catalyst in the biomass, as well as dispersion in the reactor, can significantly affect the overall reaction, and consequently the reactor performance (Demirbas, 2005).

2.7.3 Rate of decomposition of hydrolysis products during hydrolysis

The rate of decomposition of the products during the hydrolysis process depends on temperature, acidity, reaction time and the concentration of sugars. Under hydrolysis conditions that produce a solution containing in excess of 10 percent glucose, reversion phenomena are suggested to be very important. The reversion phenomena result in much of the glucose being present not as free glucose but as dimers, oligomers, and an hydro sugars which are unavailable to the microorganism used in fermentation (Harris et al., 1984). It was recently reported that metals and /or metal ions can also catalyze glucose decomposition during acid hydrolysis of Lignocellulosic materials.

2.8 Factors Affecting Fermentation

Microorganisms for ethanol fermentation can best be described in terms of their performance parameters and other requirements such as compatibility with existing products, processes and equipment. The performance parameters of fermentation are temperature, pH, alcohol tolerance, growth rate, productivity, osmotic tolerance, specificity, yield, genetic stability, and inhibitor tolerance (Demirbas, 2005).

2.8.1 Effect of sugar concentration

The concentration of sugar can affect the microbial ethanol fermentation in various ways. Use of concentrated sugar substrate is one of the ways to obtain high ethanol yield during fermentation. The amount of ethanol produced is proportional to the amount of sugar added; thus, high sugar concentrations are desired. However, too high sugar concentrations can inhibit metabolism due to increased osmotic pressure. Very low levels of sugar may limit the rate of ethanol production. Hence, each fermentation process will have an optimal glucose or equivalent sugar concentration. A sugar concentration of 10-18% is usually satisfactory, although other concentrations are used (Dunn, 1959).

2.8.2 Effect of temperature

Temperature has an important factor on the growth rate of the microorganisms and the rate of ethanol production. Too high temperature kills yeast, and low temperature slows down yeast activity and growth. Thus, specific range of temperature is required. All the recombinant strains are mesophilic organisms and have best function between 30°C to 37 °C. Operating at greater temperatures is desirable for the following reasons: 1) High fermentation temperature increases growth rate and productivity exponentialy,2) Plant capital cost is less due to higher productivity per unit volume of ferment, 3) Contamination risk is less as fewer organisms exist at high temperatures. The enzyme hydrolysis process for saccharification able to operate up to 55 °C may be combined with fermentation, further reducing capital and glucose inhibition (Dunn, 1959).

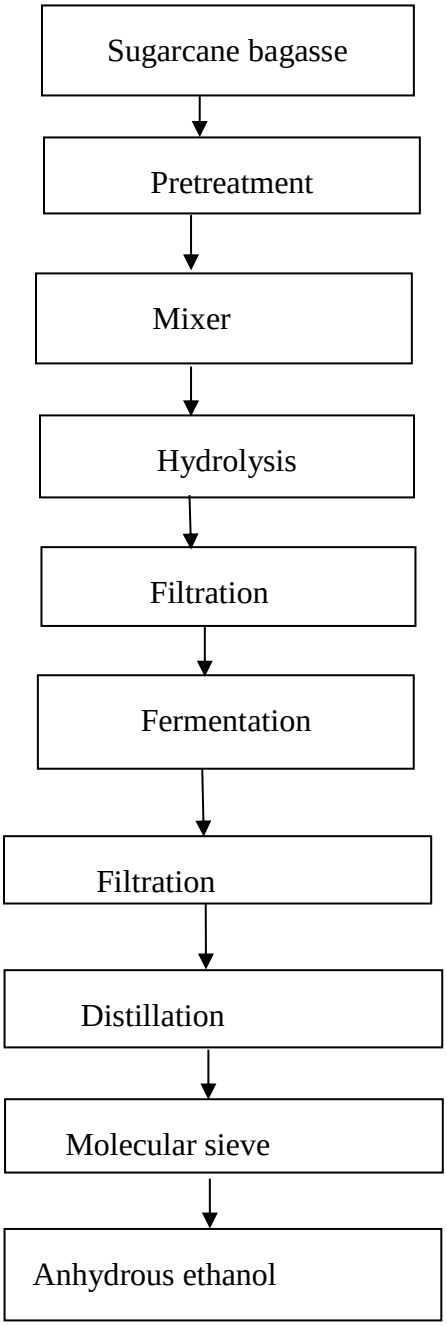
2.8.3 Effect of pH

A very important factor for cellular growth is external pH. Most alcoholic yeast fermentations are conducted below pH 4.5, although this may not be the optimal pH for growth or ethanol production. Yeast cultures can grow over a wide range from 3 to 8 with an optimum for growth generally in the slight acidic range. Shifts in pH can also affect the final ratio of organic waste products produced by yeast cultures. Thus, the optimal pH for a fermentation process must support a balance among ethanol production, cellular growth, and physicochemical effect on waste product pathways. Low pH values in yeast fermentation help to inhibit growth of contaminating bacterial cultures (Dunn, 1959).

2.8.4 Ethanol concentration

Concentration of ethanol in the fermentation broth can directly affect the growth rate of the culture and its ability to convert sugar to ethanol. Inhibitory and toxicity level of ethanol vary from culture to culture. Higher temperature lowers the tolerance of the organism. At temperatures above 35°C, current strains lose viability at ethanol concentration of 10% (Balat, 2011).

Block Flow Diagram (BFD



2.9 Ethanol Production in Global

The production of ethanol is increasing worldwide due to various driving factors explained in the preceding sections. The production in 1990 was only 4 billion gallons and it took 15 years for the quantity to double to around 8 billion gallons in 2005. But in recent years it only took three years to double again to around 17 billion gallons in 2008 and in 2011 around 23 billion gallons of ethanol is produced annually worldwide. Moreover, predictions indicate that the production would reach 34 and 48 billion gallons by the year 2020 and 2030 respectively as shown in Figure 2:1. With this the global future demand of ethanol is expected to surpass the supply which signifies that there will be market opportunities for low cost producer in developing countries, especially for tropical countries with low labor and land costs (Yacob, 2013).

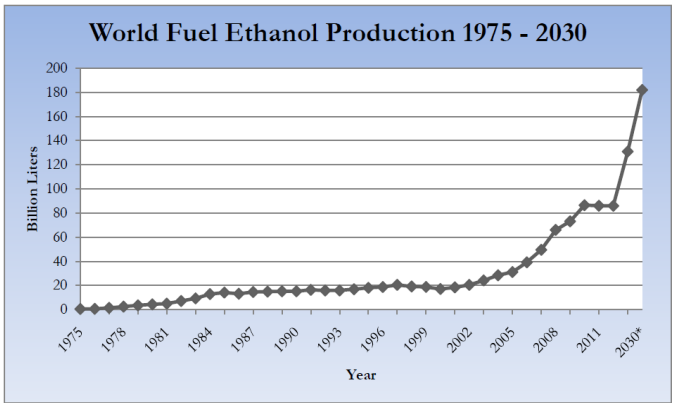


Figure 2: World fuel ethanol production trend Source: (Yacob, 2013)

Ethanol Production in Ethiopia

Ethanol production in Ethiopia is linked with sugar factories and aimed for import substitute of petroleum products, enhance agricultural development and agro processing, job creation, and export earnings. However, only a small fraction of the potentials is utilized yet, 5% blend has accessed only in the capital city of the country. Moreover, at present only two of the sugar factories, Finchaa and Metehara, are producing ethanol (Gebreegziabher et al., 2014).

Previously, there was only one biofuel factory in Ethiopia, a power alcohol plant that has been producing ethanol as a byproduct at Finchaa Sugar Factory. Finchaa has a distillery,

an ethanol plant annexed to its sugar mill with a capacity of 12 million liters per year. The plant was commissioned in 1998 and produces ethanol from sugarcane molasses, it had a stock of about four million liters of ethanol at the end of December 2001. However, although the government had issued a directive allowing Finchaa to produce and sell fuel alcohol to oil companies, who would in turn blend it with gasoline and distribute it to motorists, it could not sell its fuel alcohol on the market at that time. The major reasons for the refusal of the oil companies appeared to be the need for rehabilitating the existing old fuel stations and lack of interest in investing in a fuel sales operation that gives them little profit. This was also viewed as a lack of understanding and absence of commitment to alleviate one of the major problems of the country (Gebreegziabher et al., 2014).

Meanwhile, the corporation will also boost the current 11.1 million liters of annual ethanol production capacity of the country to 181.6 million liters and the current 100 MWh annual electrical energy generated through cogeneration to 607GWh and will enable the country to export 623,000 tons of raw sugar and 623,000 tons of white sugar which in total makes the amount 1,246,000 tons as a source of export earnings by the end of the GTP period. It also allows to use fuel ethanol to substitute imported gasoline through blending and to replace imported kerosene from abroad by the extra ethanol produced in order to minimize the foreign currency the country spent on oil import (Yacob, 2013).

CHAPTER THREE

3. MATERIALS AND METHODS

The purpose of this section is to describe to evaluate preparation of ethanol from different amount of grinded sugarcane bagasse, to analysis efficiency of ethanol through experiment at different concentration of dilute sulfuric acid at the stages of pretreatment, hydrolysis, fermentation and distillation, to perform the basic material and energy balance on specific unit operation and to determine the feasibility aspects of ethanol preparation from bagasse in the laboratory ,and to examine procedure of ethanol production from sugarcane bagasse's by Saccharomyces cerevisiae. The experiments of preparation of ethanol from sugarcane bagasse were carried out in the laboratories of Chemical Engineering at Wolkite University college of Engineering and Technology.

3.1 To evaluate preparation of ethanol

To perform this analysis, the materials and chemicals required are listed as follows with their functions.

Material required

- Plastic bags: - to collect and transport samples to the laboratory.
- Digital and non-digital driers or ovens: - to dry the sample.
- Crushers: - to crush the dried sample.
- Sieves: - to sieve the crushed sample to the particle size of below 1mm.
- Balances: - to weight samples and yeast.
- Digital pH meter: - to measure the pH of the hydrolyzates before fermentation.
- Vessels: - to hold samples and additives for hydrolysis, fermentation and distillation experiments.
- Centrifuge: - to separate the soluble liquid from non-soluble part.
- Graduated cylinder: - for volume measurement.
- Stove: - for sterilization and hydrolysis.
- Fermentation and distillation setups: - to ferment and distill respectively.

Chemicals Required

- 98% Sulfuric Acid (H_2SO_4):- used as a pretreatment and hydrolysis.
- Sodium Hydroxide (NaOH):- used to adjust the pH of soluble cellulose and hemicelluloses before fermentation.
- Urea: - used as media preparation.
- Dextrose sugar: - used as media preparation.
- Mg SO_4.7 H_2O:- used as media preparation.
- Ammonium sulfate - used for media preparation.
- Yeast (saccharomyces cerevisiae): used to ferment glucose to ethanol.

3.2 To analysis efficiency of ethanol through experiment

Sugarcane bagasse were collected from Wolkite city market, Gubre in Cheha district market and prepared for pretreatment, hydrolysis, fermentation and distillation. Sample preparation process includes, manual size reduction with cutter, drying, grinding and sieving after the samples were collected. The drying process was takes place in digital oven at 75 ^oC for 24h to prevent decomposition of sugarcane bagasse during storage (Hauser, 2008, Duhan et al., 2013). The dried sugarcane bagasse using by oven.

Pretreatment of Bagasse

About 1.5 kg of post-harvest sugarcane bagasse is taken and dried to remove all the moisture present in it. This dried bagasse undergoes size reduction by the help of a grinder. The powdered form was sieved by sieve in order to ready for hydrolysis. The effect of pretreatment of lignocellulosic materials has been recognized for a long time. The purpose of the pretreatment is to remove lignin and hemicellulose, reduce cellulose crystallinity, and increase the porosity of the materials.

Hydrolysis

The cellulose molecules are composed of long chains of glucose molecules. In the hydrolysis process, these chains are broken down to "free" the sugar, before it is fermented for alcohol production. Though hydrolysis is of many types, dilute acid hydrolysis is an easy and productive process. Also the amount of alcohol produced in case of acid

hydrolysis is more than that of alkaline hydrolysis. Concentrated acid hydrolysis is not used as it is a hazardous and corrosive process and also acid has to be separated out after hydrolysis for the experiment to be feasible.

Steps involved in dilute acid hydrolysis are:-

- One of 250ml conical flasks were taken and 20.76g of grinded sugarcane bagasse is added and another 250ml of conical flasks were taken and 14g of grinded sugarcane bagasse is added.
- Another flask of 500ml size is taken and to it 60g of grinded sugarcane bagasse is added carefully.
- About 24.96ml of dilute sulfuric acid of concentration 0.2M is added to the 500ml flask.
- 16.4ml of dilute sulfuric acid of concentration 0.3M is added to one of the 250ml flasks.
- 66.8ml of dilute sulfuric acid of concentration 0.5M is added to the remaining one 250ml flasks.
- All this samples are left to be soaked in dilute sulfuric acid for 24 hrs.
- The bottles were then capped with the help of cotton plugs.

PH Adjustment

Before addition of any micro-organism to the above prepared samples, pH of these samples has to be adjusted. Otherwise the micro-organism will die in hyper acidic or basic state. A pH of around 4.5-5 is maintained.

Steps involved in pH adjustment are:-

- The 500ml flask containing 0.2M dilute sulfuric acid hydrolyzed bagasse is taken and its pH is checked with the help of a pH-meter.
- As samples are acid hydrolyzed, a highly basic solution is added to bring the pH in the range of 4.5-5.
- For this purpose, a highly concentrated NaOH solution is prepared by mixing water with Na pellets.

- This NaOH solution is added drop wise to the 0.2M 500ml flask with constant stirring until the pH reaches to a range of 4.5-5.
- If suppose the pH goes beyond 5, concentrated HCl acid is added drop wise to maintain the pH in the range.
- The above steps are repeated for the 0.3M and 0.5M dilute sulfuric acid hydrolyzed bagasse.

Fermentation

Media preparation

For preparing 100ml media, we add

Sugar (Dextrose) = 10 g

Yeast extract = 0.2 g

Magnesium sulfate = 0.04 g

Ammonium sulfate = 0.2 g

Make-up water = 100 ml

(In case Magnesium sulfate and Ammonium sulfate are not available 1g of urea can be used).

Steps involved in fermentation are:-

- To the above 100ml media, 0.5g of yeast (Saccharomyces cerevisiae) is added in a 250ml conical flask.
- This conical flask is then placed in a shaking incubator for 24 hrs.
- 10ml of this medium is then added to each of the three autoclaved samples.
- The flasks are properly covered with cotton plug.
- These flasks are then placed in the shaking incubator at a temperature of 35^{o}C and 120 rpm after 24 hrs the flasks are covered with aluminum foils over the cotton plug.

Distillation

Distillation was the last step in the production of ethanol from bagasse experiments. It is the purifications steps. Distillation is the method used to separate two liquid based on their different boiling points. However, to achieve high purification, several distillations are required. In this experiment separation were used by rotary evaporator at a temperature of 78.3^{o}C for 3hrs.

Components of experimental setup

- Special top-fit of distillation vessel
- Condenser
- Condenser tubing
- Beaker
- Distillation vessel

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Experimental Results

The process consists of four parts: pretreatment to remove lignin, reduce cellulose crystallinity, hydrolysis the bagasse and increase the porosity of the materials, dilute acid hydrolysis and fermentation to produce ethanol, distillation to remove the ethanol. After following the above series of procedure, the experimental outcomes of those particular results are measured for their efficiency by recording time and temperature to know the yield of ethanol concentration.

Table 6: Summary of experimental result

Concentration of dilute sulfuric acid (M)	Mass(g)	Volume(ml)	Density(g/cm^3)	PH	Yield (%)
0.2	20.76	24.96	0.832	4.55	62.824
0.3	14.00	16.40	0.857	4.30	52.521
0.5	60.00	66.80	0.912	4.02	40.632

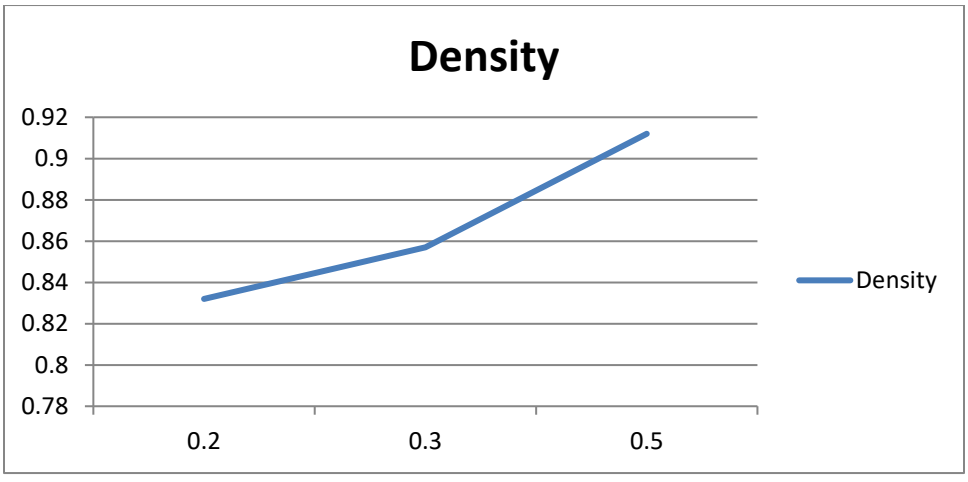


Figure 3: Concentration of sulfuric acid versus density of ethanol

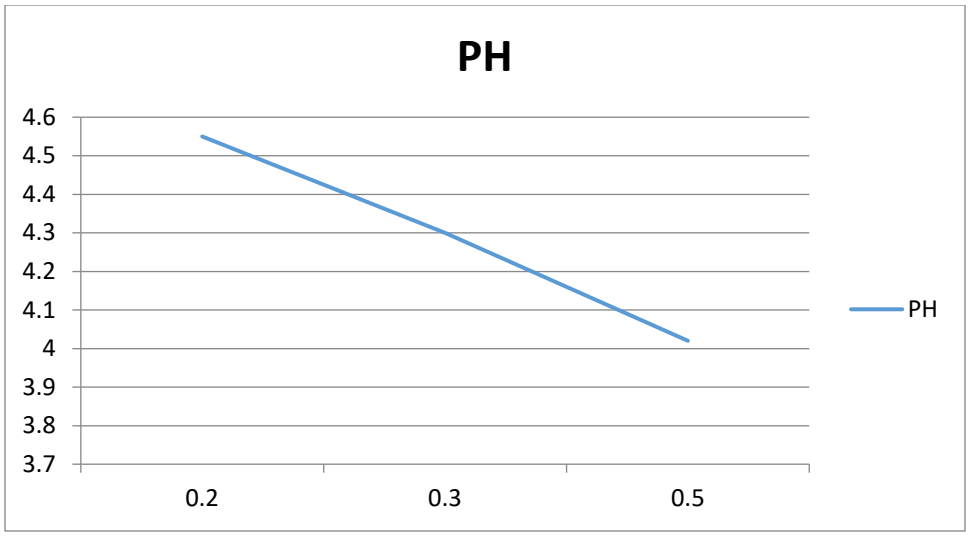


Figure 4: Concentration of sulfuric acid versus PH of ethanol

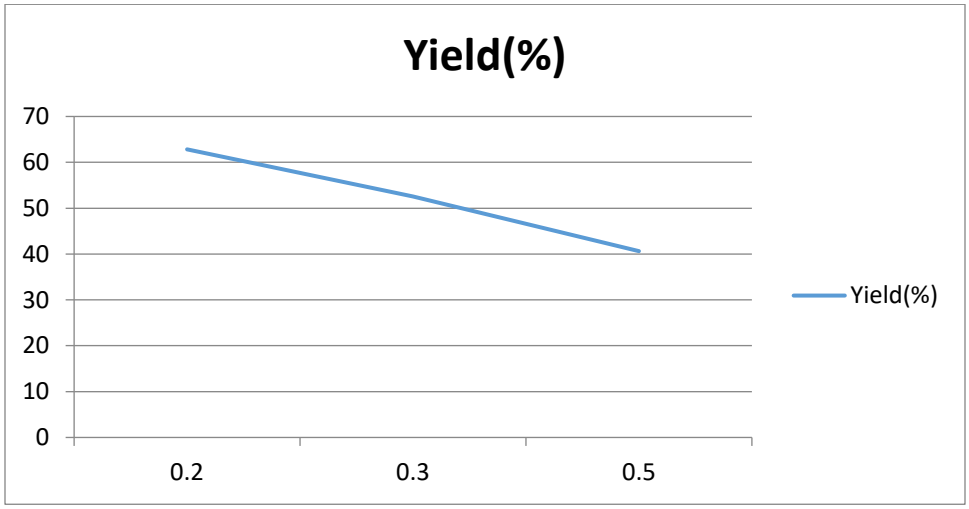


Figure 5: Concentration of sulfuric acid versus yield (%) of ethanol

4.2 Discussion

The ethanol concentration was increases with the increasing pH while concentration of sulfuric acid and density of ethanol decreases. This shows that the concentration (yield) of ethanol was high at low concentration of sulfuric acid. Therefore, with increasing molar concentration of sulphuric acid, the concentration of ethanol and sugar decreases. More amounts of ethanol and sugar were found for 0.2M than 0.3M and 0.5M when we compare each other.

CHAPTER FIVE

5. MATERIAL AND ENERGY BALANCE

Material and energy quantities, as they charge and discharge into and from process operations, can be described by material and energy balances. Such balances are statements on the conservation of mass and energy. If there is no accumulation, what goes into a process must come out. This is true for continuous operation. If no input and output during the operation carried out the process is batch process. 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. The first material balances are determined in the exploratory stages of a new process, improved during pilot plant experiments when the process is being planned and tested, checked out when the plant is commissioned and then refined and maintained as a control instrument as production continues. When any changes occur in the process the material balances need to be determined again.

The energy balance determinations are also made to determine the energy requirements of the process, the heating, cooling and power required. In this plant operation it is thought that an energy balance (energy audit) on the plant will show the pattern of energy usage and suggest areas for conservation and savings.

5.1 Material Balance

Basis:

- Working hr per day = 24
- Working day per year = 300

$$Y = C*X$$

Where, Y is industrial scale fixed (10^6 L/yr)

X is lab data (X =12ml =$12*10^{-3}$L) from lab experiment.

C is scale factor

$Y = C*X_1$, $C = Y/X_1 = 10^6 L/12*10^{-3} L = 83333333.3$

Raw material used $= 25*10^{-3}kg* 83333333.33 = 2,083,333.25kg/yr$

$M_{DB} = 2,083.3$ ton/yr * 1yr/300day*1day/24hr= 289.35kg/hr

$H_2SO_4 = 1*10^{-3}kg*83333333.33 = 833,333.3kg/yr = 115.74kg/hr$ of dilute sulfuric acid.

Yeast media = 10% mash

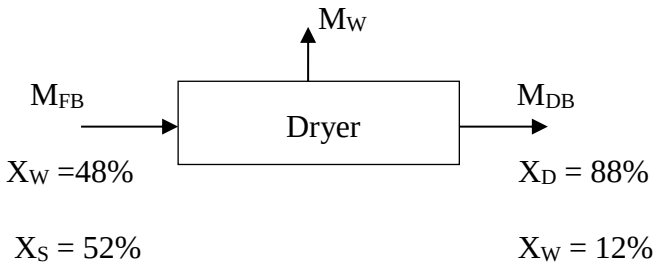
Water = 1:10 of dry bagasse

Mass balance for pretreatment

It is the method to prepare the sample for dilute acid treatment

Material Balance for Dryer

It is used to dry the wet sugarcane bagasse i.e. to make agreeable for easily crushing



Where, M_{FB} = mass flow rate of wet bagasse

X_W = fraction of water in bagasse

X_S = fraction of solid in bagasse

M_{DB} = mass flow rate of dry bagasse

X_D = fraction of dry bagasse

Component mass balance for water

$M_{FB}* 0.48 = M_{DB}* 0.12 + MW$

From over all material balance

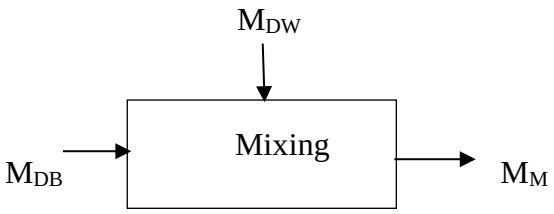
$M_{FB} = M_W + M_{DB}$

$M_w = M_{FB} - 289.35kg/hr$

From both equation, $M_W = 200.32kg/hr$ and $M_{FB} = 489.67kg/hr$

Material Balance for Mixing

It is the equipment used to make homogenous suspension of distilled water and grinded sugarcane bagasse.



Where, M_{DB} = Mass flow rate of dry sugarcane bagasse

M_{DW} = Mass flow rate of distilled water

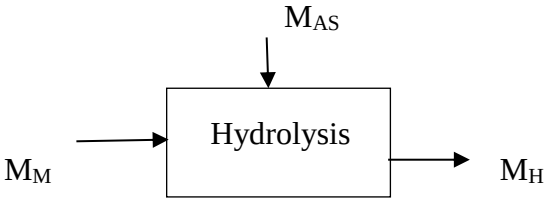
$$M_{in} = M_{out}$$

$M_{DW} = 10 * M_{DB} = 10 * 289.35kg/hr = 2893.5kg/hr$

$M_{DB} + M_{DW} = M_M = 2893.5kg/hr + 289.35kg/hr = 3182.85kg/hr$

Material balance for Hydrolysis

The pretreated sample is soaked and treated with 1% sulfuric acid to convert cellulose to glucose and serve as catalyst meaning it has no any reaction with cellulose



Where, M_M = Mass flow rate of pretreated mixture (mass of mixture)

M_{SA} = mass of diluted sulfuric acid

M_H =mass of hydrolyzed

Reaction $C_6H_{10}O_5 + H_2O \longrightarrow C_6H_{12}O_6$

1 mole of cellulose $\longrightarrow$ 1 mole of glucose for 100% conversion.

But not complete conversion and assume that 95% of cellulose converts to glucose

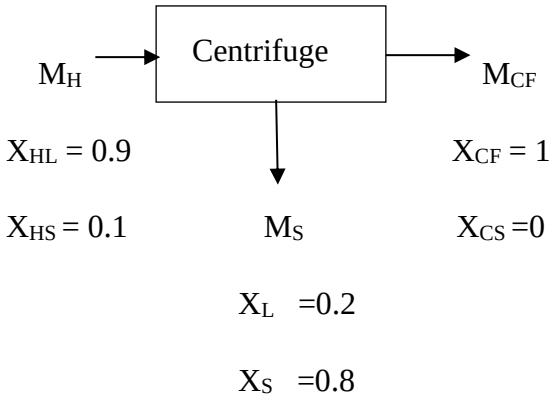
$M_H = 0.95 * M_M = 3182.85kg/hr * 0.95 = 3023.71kg/hr$

Applying total mass balance

Mass sulfuric acid (M_{SA}) = 115.74kg/hr

Material balance for centrifugal separation

Centrifuge is to use separating insoluble solid from liquid. Moisture content of centrifuge solid is 20%



Where, M_H = mass flow rate hydrolyzed

M_S = mass flow rate of bottom centrifuge solid

M_{CF}= mass flow rate of the centrifuge fluid.

From the solid component balance

$M_H * X_{HL} = M_S * X_S + M_{CF} * X_{CS}$

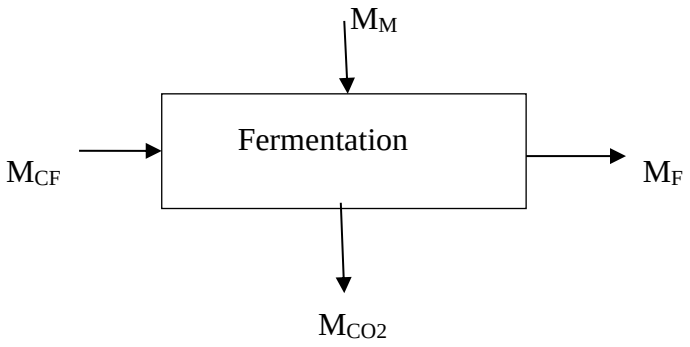
$= 3023.71 * 0.1 = M_S * 0.8 + MCF * 0$

M_S = (3023.71*0.1kg/hr)/(0.8) = 377.88kg/hr

$M_{CF} = M_H - M_S$ = 3023.71 – 377.875 = 2645.84kg/hr

Material balance for fermentation

Total material balance in the fermenter



Where, M_{CF} = mass of centrifuge (filter)

M_M =mass of media

M_{CO2} = mass of CO_2 release

M_F= mass of fermented glucose. From the reaction of fermentation

$C_6H_{12}O_6 \longrightarrow 2\ C_2H_5OH + 2CO_2$

180 gm/ mole $\longrightarrow$ 92gm/mole ethanol + 88 gm/mol $CO_2$for 100% conversion.

But 1% – 5% of glucose not changed from literature and we take the value i.e 95% efficiency

Mass of the media is 10% of the mass of filter mash, hence from the total mass balance

$M_M = 10\%M_{CF}$ = 2645.835*0.1 = 264.58kg/hr

$M_F = 0.95 * M_{CF}$ = 0.95*2645.835 = 2513.54kg/hr

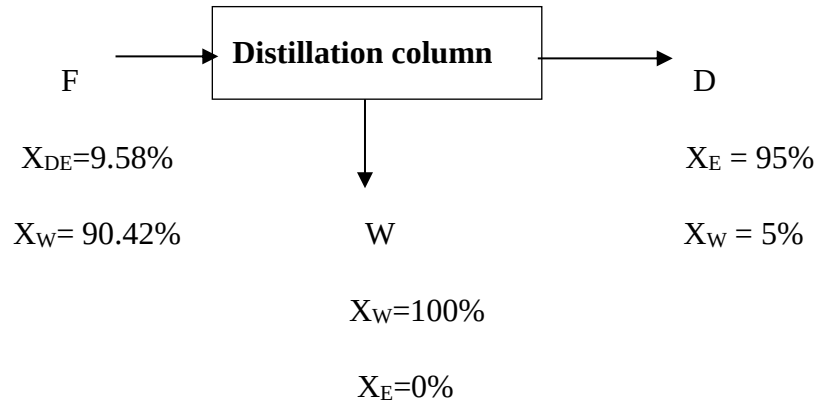
From overall balance

$M_{CF} + M_M = M_F + M_{CO2}$

MCO2 = (2645.835 + 264.58 – 2513.54) kg/hr = 396.88kg/hr

Material balance for distillation

It is the equipment used for the purification of ethanol from water-ethanol mixture. The mixture from fermentation enter in to the distillation with the mixture of 9.58% ethanol and the rest water, then after distillation column the purification of ethanol come to 95%.



Where F= Diluted hydrous ethanol

D= hydrous ethanol

W= water

X_{DE} = fraction of diluted hydrous ethanol

X_W = fraction of water

X_{HE} = fraction of hydrous ethanol

X_E =fraction of ethanol

From ethanol component balance

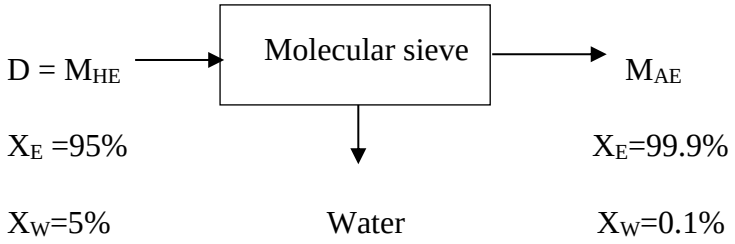
$F*X_{DE} = W*X_E + D*X_{HE}$

D = (2513.54*0.0958)/(0.95) = 253.47kg/hr

W = F-D = 2513.54 – 253.47 = 2260kg/hr

Material Balance for Molecular Sieve

It is the equipment which following the distillation column and bring the ethanol concentration from 95% to 99.9%.



Where X_E= Percentage of Ethanol

X_W= Percentage of water

From ethanol component balance

$M_{HE}*X_E = M_{AE}*X_E$

M_{AE} = (253.47*0.95)/0.999 = 241.04kg/hr

$M_W = M_{HE} – M_{AE}$ = 253.47 – 241.04 = 12.43kg/hr

5.2. Energy Balance

Energy is an important and costly input in the production process of ethanol. After feedstock costs, it is the most expensive variable cost. This energy is utilized in two forms, thermal and electrical. Electrical energy is used to run machinery with moving parts or motors such as pumps, centrifuges, and mills.

Basis one operation hours

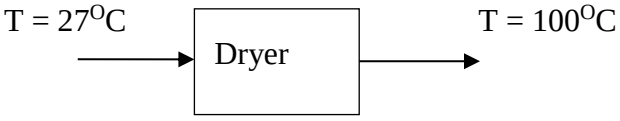
Basic data

- From vapor equilibrium data boiling point of ethanol = 78.3ºC
- Heat of capacity for ethanol = 2.673kJ/kg .k
- Heat of capacity for water = 4.2kJ/kg .k
- Latent heat of ethanol at 78 = 2224.7kj/kg.k
- Latent heat of water at 78 = 2256.9kj/kg.k

- Latent heat of steam at 10bar = 2776.2KJ/kg
- Feed of temperature of distillation =30^{o}C

Energy balance for dryer

The dryer is dried the sample by 100^{0}c from 20^{0}C



The energy required is, Q = M*Cp* ΔT

Where M =mass of wet bagasse

Cp = specific heat of wet bagasse

ΔT = Tf- Ti

Mass of bagasse from material balance =289.35kg/hr

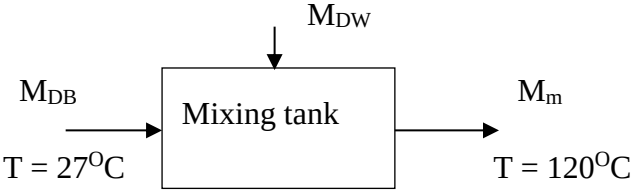
$Cp = Cp_b * X_S + Cp_W * Xw$

CP = 2.968kj/kg.k*0.52 + 4.18kj/kg.k*0.48 = 3.55kj/kg.k

Q = M* Cp* ΔT = 289.35kg/hr*3.55kj/kg.k (100-27) k = 74985.05kj/hr

Energy Balance for Mixing

It is the energy used for mix the grind bagasse powder and distilled water to make suspension.



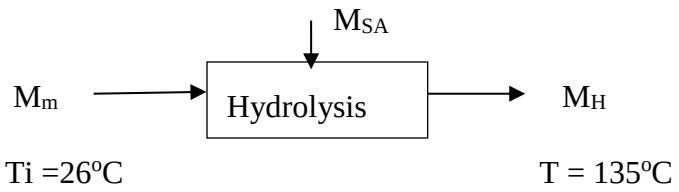
C_{PM} = (289.35*2.968 + 2893.5*4.18)/(289.35 + 2,893.5) = 4.07kj/kg.k

The heat required for mixing is

Q = M_m * Cp *ΔT = 3182.85*4.07*(120 - 27) = 1,204,740.55kj/hr

Energy balance for Hydrolysis

It is the energy used for hydrolysis cellulose to glucose



The heat required for hydrolysis is

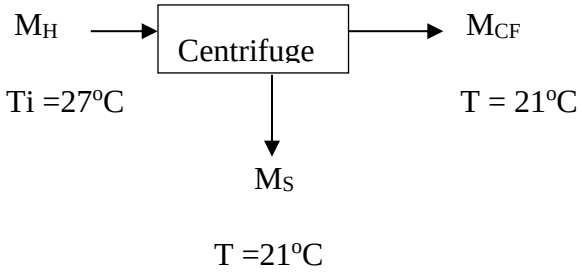
$Q = M_{m*}C_{PM*}\ \Delta T = 3023.71kg/hr*4.07kj/kg.k\ *(135-26)\ k = 1,341,408.47kj/hr$

Steam consumption

$Q = M_S{}_*Cp\ *\Delta T + h_{lw}$

$M_S = \frac{Q-hlw}{CP\Delta T} = (1,341,408.47 - 2256.9)/[4.18(135\ -26)] = 2,939.19kg/hr$

Energy balance for centrifugal separation

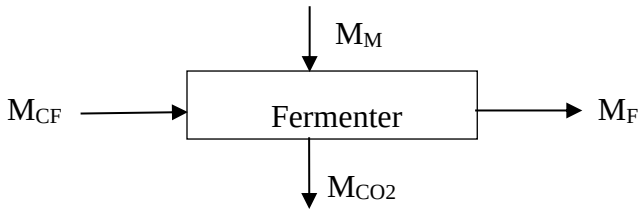


$C_{PS} = [(2645.84*0.8*3.55) + (2645.84*0.2*4.18)]/2645.84 = 3.7kj/kg.k$

$Q = M_S\ *Cp\ *\Delta T + M_{CF}{}_*Cp\ *\Delta T$

$2939.19*3.7(27-21) +2645.84*4.18(27-21) = 131,607.85\ kj/hr$

Energy balance for fermenter



Fermentation is an exothermic reaction heat will be generated inside the fermenter and the outlet temperature is 30^0C. The energy balance in the fermenter at 0^0C reference temperature.

Data

C_p of mix at 30^0C = 4.142kj/kg.k

C_p of C_{O2} at 30^0C = 0.846kj/kg.k

$Q_{MIX} = Q_{CO2} + Q_F + Q$

$Q = Q_{MIX} - Q_{CO2} - Q_F$

$Q = M_{MIX} * Cp_{MIX} * \Delta T - M_{CO2} * Cp_{CO2} * \Delta T - M_F * C_{PF} * \Delta T$

$C_{PF} = CP_{MIX} * X_{MIX} + C_{PCO2} * X_{CO2}$

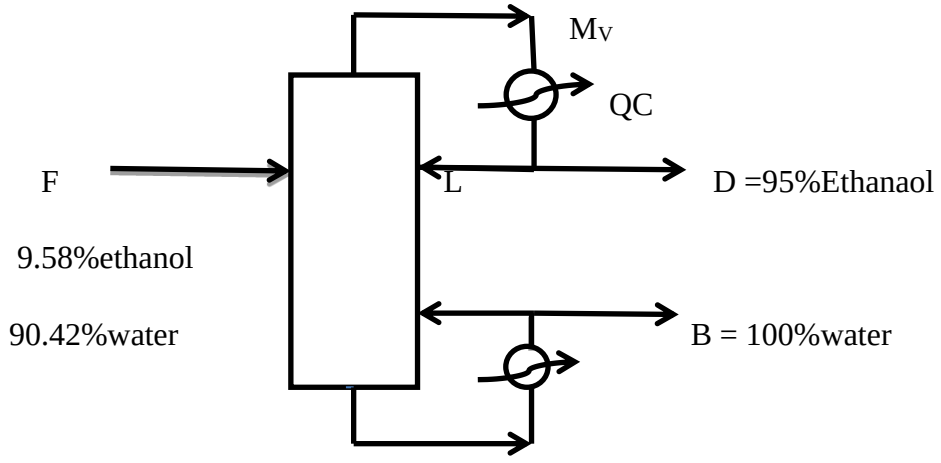
$X_{CO2} = 396.88/ (396.88 + 2645.84) = 0.13$

$X_{MIX} = 1-0.13 = 0.87$

$C_{PF} = 4.142*0.87+ 0.846*0.13 = 3.7$kj/kg.k

Q =2645.84*4.142(30-0) -396.88 *0.846(30-0) - 2513.54*2.92(30-0) = 98,513.16kj/hr

Energy balance on distillation column



Basis 27^0C, 1hr

Heat capacity on top

$CP_D = 0.95*2.47 + 0.05*4.18 = 2.56$kj/kg.k

Heat capacity on bottom

$CP_W = 4.18$kj/kg.k

Balance around the main condenser

Reflux ratio, R = 2.5

$R = \frac{L}{D}$, L = 2.5D

L =2.5*253.47 = 633.68kg/hr

$M_V = L+D = 633.68+253.47 = 887.15$kg/hr

From vapor equilibrium data

Boiling point of 95% alcohol = 78.3^0C

At steady state

Input = Out put

$H_F = H_D + H_L + Q_C$

$Q_C = H_F - H_D - H_L$

Assuming complete condensation

Enthalpy of Vapor = Latent + Sensible heat

$H_V = M_v * ʎ_v + M_v * Cp * \Delta T$

$= 887.15*789 + 887.15*2.56(78.4-27) = 816{,}696$kj/hr

Where:

QB = re-boiler heat input

QC = condenser cooling

QB is supplied by condensing steam

Q_B = is determined from a balance over complete system.

Input = Out put

$Q_B + H_F = Q_C + H_D + H_W$

$Q_B = Q_C + H_D + H_W - H_F$

Heat capacity of feed

$H_F = M_F * Cp * \Delta T$

$CP_F = 0.0958*2.47 + 0.9042*4.18 = 4.02 kj/kg.k$

HF = 2513.54*4.02(30-27) = 30,313.3kj/hr

Heat capacity of bottom

$H_W = M_W * Cp * \Delta T$

H_W= 2260*4.18(100-27) = 689,616kj/hr

$Q_B = Q_C + H_D + H_W - H_F$

Q_B = 816,696kj/hr + 0 + 689,616kj/hr – 30,313.3kj/hr = 1,475,998.7kj/hr

Latent heat of steam from literature

ʎv = 2260KJ/kg

M_S = 1,475,998.7/2260 = 653kg/hr

Q_C is removed by cooling water with a temperature rise of 30^0C

$Q_C = M_W * CP * \Delta T$

$M_W = \frac{QC}{CP\Delta T}$ = 816,696/ (4.18*30) = 6512.7

CHAPTER SIX

6. EQUIPMENT SIZING

Assumption:

All tanks are 85% full or 15% safety factor.

Sizing of equipment is depending on the material balance calculated on the above section.

Basis: one day

6.1 Sizing of Main Equipment

- Drier
- Hydrolysis
- Fermenter tank
- Distillation column

Table 7: Sizing of storage tank for dried bagasse

1	Material of construction	Carbon steel
2	Material handle	dried bagasse
3	Density of bagasse	200kg/m^3

Density = mass/volume

Volume of bagasse =mass/density= 289.35kg/hr/(200kg/m^3)= 1.45 m^3/hr

Storage tank volume = 1.45/0.9 = 1.6m^3 including 15%safety factor

Storage tank for the mixing of water and bagasse powder

Slurry to be handled water and bagasse powder mixture

Density of liquid 0.1*200 + 0.9*1000 = 920kg/m^3

Temperature of liquid 25^0C

Materials of construction carbon steel

Capacity (V) = 3182.85kg/hr/920kg/m^3 = 3.84m^3 including safety factor (10%)

Table 8Sizing of ethanol storage tank

1	Material of construction	Carbon steel
2	Material handled	Ethanol
3	Density	0.789kg/lit=789kg/m^3

Volume of ethanol = 253.47kg/hr/(789kg/$m^{3)}$ = 0.32m3/hr

V0lume of the storage tank = 0.32/0.85 = 0.38m^3 including 15% safety factor

Table 9: Sizing of Hydrolysis Reactor

1	Material of construction	Carbon steel
2	Density of the mixture	1104kg/m3
3	Material handled	Glucose

Assume 15% of safety factor

V = mass of the hydrolyzate/density

= 3023.71kg/hr /1104kg/m^3 =2.74m3/hr

V_{vessel} = 4.5m3/hr = 3.22m^3 including 15%safety factor.

Table 10: Sizing on fermenter tank

1	Operation	batch(12hr/batch
		Fermentation period=6days
		1 day= 24hr/12hr/batch =2 Batch
2	Material of construction	Carbon steel
3	Size	Dome shaped

4	Temperature	30oC
5	Density	1062.4kg/m3

Volume = mass/density = (2513.54)/1062.4 = 2.37m^3/hr

Total No of fermenter with 6 days duration of fermentation = 12 fermenter

Volume of the fermenter = 2.37/0.85 =2.78m^3 including 15% safety factor

Table 11: Sizing/design of distillation column

No.	Streams with flow rate	Component composition (%)
1	Feed=2513.54kg/h	XHE=9.58
		XW =90.42
2	Bottom =2260kg/hr	XHE=0
		XW =100
3	Distillate=253.47kg/hr	XHE=95
		XW =5

Operating conditions

No.	Conditions
1	Reflux ratio=2.5
2	Working pressure=0.6bar
3	Vapor velocity=0.8m/s
4	Molecular weight of ethanol=46g/mol
5	Molecular weight of water=18g/mol
6	Boiling point of ethanol=78^{o}C=351.3K

7	Boiling point of water=100^{o}C=373K

Feed mean molecular weight = 46*0.0958+18*0.9042 = 20.68g/mol

Cp of feed = 0.0958*2.72+0.9042*4.18 = 4.04kj/kg.k

Ethanol mole fraction feed = $\frac{9.58/46}{\left(\frac{9.58}{46}\right)+\frac{90.42}{18}}$ = X_f = 0.04

Ethanol mole fraction at the bottom = $\frac{\frac{0}{46}}{\frac{0}{46}+\frac{100}{18}}$ = X_W = 0

Ethanol mole fraction at the distillate = $\frac{\frac{95}{46}}{\frac{95}{46}+\frac{5}{18}}$ = X_D = 0.88

Water mole fraction at the feed = $\frac{90.42/18}{\left(\frac{90.42}{18}\right)+\frac{9.58}{46}}$ = 0.96

Water mole fraction at the bottom = $\frac{100/18}{\left(\frac{100}{18}\right)+\frac{0}{18}}$ = 1

Water mole fraction at the distillate = $\frac{5/18}{\left(\frac{5}{18}\right)+\frac{95}{46}}$ = 0.12

X_F= 0.04, X_D = 0.88, X_W = 0

Molar latent heat of mixture in feed

λ = 0.0958*790 + 0.9042*2376.7 = 2224.7kj/kg

Boiling point (average) of feed = 0.04*351.3 + 0.96*373 = 372k = 99^{o}C

Heat capacity of the feed, C_{PF} = 3.85kj/kg.k

Q = $\frac{CpdT+\lambda}{\lambda}$ = $\frac{3.85*(372-298)+2224.7}{2224.7}$ = 1.13kj/kg.k

Y-intercept = X_D/R+1 = 0.88/ (2.5+1) = 0.25

Vapor liquid equilibrium data for the mixture can be calculated in the table

Y = αx/1+ (α-1) x, Taking relative velocity = 2.5

Slope = $\frac{q}{q+1}$=$\frac{1.13}{1.13+1}$ = 0.53

X	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.96
Y	0	0.217	0.385	0.517	0.625	0.714	0.789	0.854	0.906	0.957	0.984

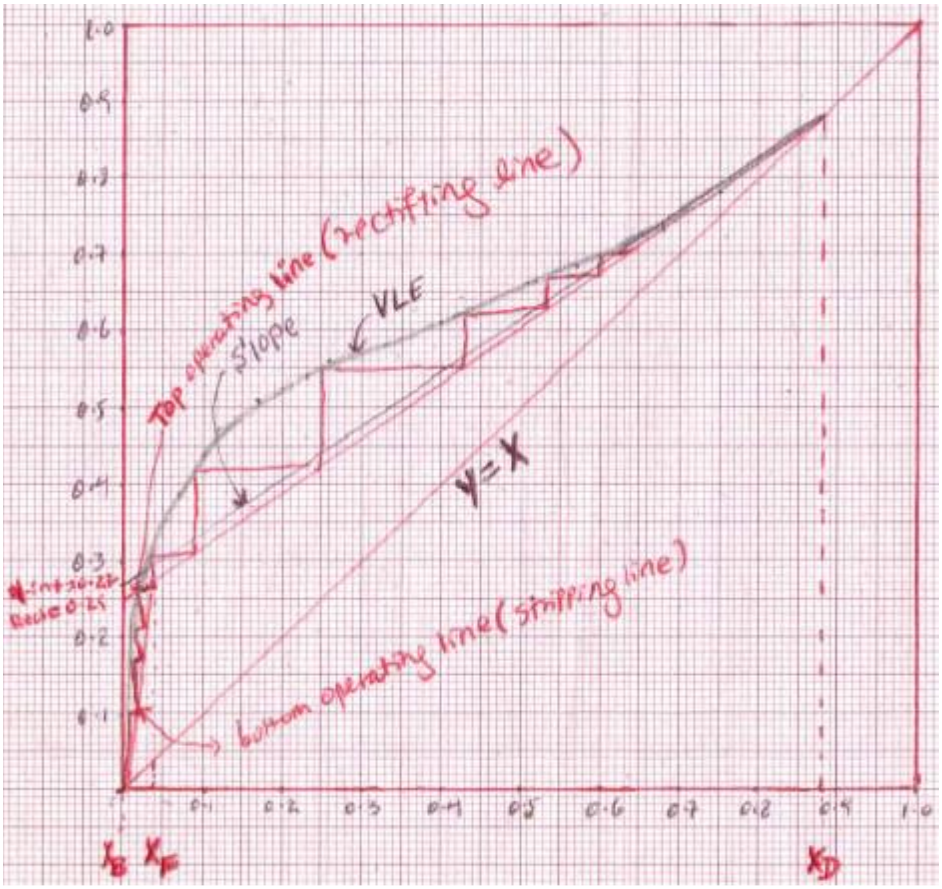


Figure 6: McCabe-Thiele diagrams to determine number of stage

With the above information, number of theoretical plate is 10 and feed is introduced at the 9 stages Temperature at the top is 85^0C (358k), assumed

Assuming ideal gas behavior $V = \frac{nRT}{P}$, where n is taken the vapor load at V = L+D = 887.15kg/hr

n = [(887.15*0.95)/46] + [(2260*0.5)/18] = 81kmol/hr

R= 0.082atm.m^3/kmol.k, P= 0.4atm

V = (81*0.082*358)/0.4 = 5944.6m^3/hr

Condenser design

The condenser to be used is a horizontal condenser design to condense 245.2kg/hr of distilled ethanol at 25^0C by exchange with water at 20^0C and out let temperature of 30^0C. Fluid allocation is given tube side to water and shell side to ethanol.

Specification

Permissible pressure drop on both sides is 0.8bar

Fouling factor

Distilled ethanol = 0.0001 $m^2\ ^0$C /w

Water = 0.0003 $m^2\ ^0$C/w

The mean temperature of ethanol = $\frac{85+30}{2}$ = 57.5^{o}C = 330.5k

At this temperature the C_P of ethanol is

Cp = A + BT = 8.424 + 44.422*10^{-2}*330.5

= 155.24kJ/kmol

= 155.24kJ/kmol * kmol/46kg *k = 3.375kJ/kg.k

Heat duty =253.47kg/hr/(3600sec) * 3.375kj/kg.k(85-30) = 13kw

As the first trial the mean temperature of water is equal to the inlet temperature, thus Specific heat capacity of water at this temperature = 13kJ/kg.k

Energy balance of the previous

Mw = 2260kg/hr

[2260kg/hr/3600sec]*4.18(T_2-20) = 13kw

T_2 = 24.98^{o}C

The mean temperature of water is

T_2 = (24.98 + 25)/2 = 24.99^{o}C

Overall coefficient

For condenser of this type the overall coefficients will be between 700-1000w/$m^2.^0C$ (Coulson Vol, IV, 2005). So, we start with 700w/$m^2\,^0C$.

Condenser type and dimension

Even number tube pass is selected to simplify the pipe work

Start with one shell pass and two tube pass

$$\Delta Tlm = \frac{(85-24.49)-(30-20)}{\ln[\frac{85-24.49}{30-20}]} = 28.06^oC$$

$$R = \frac{85-30}{24.49-20} = 12.25$$

$$S = \frac{24.49-20}{85-20} = 0.07$$

From the graph of temperature correlation factor (Coulson Vol, IV, 2005)

$F_t = 0.96$

So $\Delta T_{lm} = 0.96*28.06 = 26.9^0C$

Heat transfer area

$$Au = \frac{Q}{U\Delta T} = 13000/(700*26.9) = 0.69m^2$$

CHAPTER SEVEN

7. COST ESTIMATION

7. 1 Economic Analysis

The economic analysis is performed according to the purchased equipment cost, raw material cost and other related cost.

The economics is evaluated based on the following step

- Listing the purchased equipment cost, raw material cost, utility cost, labor cost based on the number of operating labor.
- Determining the total production.
- Determining total capital investment.
- Profitability analysis.

7.2 Purchased equipment cost

Table 12: Purchased equipment cost from 2016 cost value (www.mache.com. cost)

Eq. No.	Equipment Name	Capacity	Qty	Material	Unit price($/unit)	Total price($
1	Drum drier	1,600	1		7,000	
2	Mixing tank	3,800	1	carbon steel	14,500	
3	Hydrolysis Reactor	3,220	1	carbon steel	81,900	
4	Centrifuge	2,800	1	carbon steel	12,000	
5	Fermenter	2,800	12	carbon	28,600	343,200

				steel		
6	Distillation	380	1	stainless steel	12,100	
7	Condenser	0.69m^2	1	carbon steel	4,400	
8	Molecular Sieve	400L	2	carbon steel	2,300	4,600
Total cost						$575,640

Total cost of the equipment's including 20% extra for any other accessories = $575,640

7.3. Estimation of Capital Investment

Table 13: Direct Cost and Indirect Cost

Direct cost(DC)	**Factor**	**Cost (US,$)**
Purchased equipment	1	575,640
Purchased equipment Installation	0.40	230,256
Instrumentation(installed)	0.18	103,615.2
Electrical installed	0.25	143,910
Piping(installed)	0.45	259,038
Buildings including service	0.13	74,833.2
Yard improvement	0.1	57,564
Service facilities installed	0.3	172,692
Land	0.06	34,538.4
Total Direct Cost		1,652,086.8

Indirect cost(IDC)	**Factors**	**Cost(US,$)**
Engineering and Supervision	0.21	120,884.4
Construction expenses	0.1	57,564
Contractors fee's	0.05	28,782
Contingency	0.1	57,564
Total Indirect Cost		264,794.4

Fixed capital investment = total direct cost + total indirect cost

= $1,652,086.8 + $264,794.4

= $ 1,916,881.2

Total capital investment (TCI) = fixed capital investment (FCI) + working capital cost (WC)

$$TCI=FCI+WC$$

since, working capital cost= (10-20) % of total capital investment, taking an average of 15%

$$TCI =FCI+0.15TCI$$

$$TCI=FCI/0.85$$

$$TCI=1,916,881.2 /0.85 = \$2,255,154.4$$

There for, the working capital cost (WC) =0.15*2,255,154.4 = $338,273.2

7.4 Estimation of Total Product Cost

Manufacturing cost

Manufacturing cost = Direct production cost + Fixed charges + Plant overhead cost.

Variable Operating Costs

Variable operating costs, which include raw materials, waste handling charges, and by-product credits, are incurred only when the process is operating. Quantities of raw materials used and wastes produced were determined using the material balance.

Table 14: Production cost (variable cost)

No	Item		Cost(US,$)
1	Raw material	$0.0125/kg*3,525,624	440,703
2	Operating labor	60*1400*12	1,008,000
3	Direct supervisors and clerical labor	12%operating labor	120,960
4	Utilities (electrical and water cost)	151,750+10,505	162,255
5	Maintenance and repairs	0.06FCI	115,012.9
6	Operating supplies	.0.0075FCI	14,376.6
7	Laboratory charges	Not applicable	
8	Patents and royalties	Not Applicable	
Total direct production cost		1,861,307.5	

Fixed Operating Costs:

Fixed operating costs are generally incurred in full whether or not the plant is producing at full capacity. These costs include labor and various overhead items

Table 15: Fixed Operating Costs

No	Item		Cost(US,$)
1	depreciation	0.1FCI	191,688
2	Local taxes	0.02FCI	38,337.6
3	insurance	0.005FCI	9,584.4
4	Rent	0.006(Land and Building)	4697.3
Total fixed charge		244,333.5	

Plant overhead cost

No.	Item		Cost(US,$)
1	Plant overhead cost	2*3000*12	72,000

Manufacturing cost=Direct production cost + Fixed charges + Plant overhead cost

=1,861,307.5+244,333.5+72,000=$2,177,641

General Expense Cost

No	Item		Cost(US,$)
1	Administrative cost	0.35L=0.35*1008,000	352,800
2	Distribution and selling	0.15L=.15*1,008,000	151,200

3	Research and development		Not Applicable
4	Financing (interest)		Not Applicable
Total general expense		504,000	

Total production cost = manufacturing cost + general expense

=$2,177,641 +504,000 = $2,681,641

TPC = $2,681,641

Variable cost = $1,861,307.5

Fixed costs = fixed charges (except depreciation) + plant overhead cost

= 244,335 + 72,000 = $316,335

Depreciation cost = $191,688

General expense = $504,000

7.5 Gross earnings cost

Basis: -working hour = 24hr/day

Working day = 300day /yr

Product per year is 380L/hr*300day/yr *24hr/day = $2.74*10^6$L/yr of ethanol

Unit sell price = $1/lit

Total selling price is = $2.74*10^6$L/year x $1/L= $2,740,000

Gross income = Total Income – Total Product Cost

= ($2,740,000 - $2,681,641) = $58,359

Depreciation = $191,688.12

Plant life (n) = 10 year, M_{ar}= 12%

Let the Tax rate be 30% (common)

Net Profit (NP) = Gross income - Taxes = Gross income× (1- Tax rate)

NP= $58,359 × (1- 0.3) = $40,851.3

Annual Cash Flow (Aj)

Annual cash flow (Aj) =NP +Dj =$40,851.3 + $191,688

= $232,539.3

Rate of Return on Investment (ROI):

Rate of return = (Net profit/ Total Capital Investment) ×100

= ($40,851.3 / 2,255,154.4) ×100 = 0.18

= 18%implies, the project or theses is feasible because ROI is greater than minimum acceptable rate of return (Mar).

That is 18 % > 12%

Payback Period (PBP):

Project life is assumed 10 years and we use straight line method

Depreciation = $\frac{\text{FCI}}{10} = \frac{1{,}916{,}881.2}{10}$ =$191,688.12

Vs = salvage value of property at end of service life assume that = 0

PBP = $\frac{\text{Total fixed capital investment} - \text{salvage value}}{\text{average profit per year} + \text{Average depricition per year}} = \frac{\$1{,}916{,}881.2 - 0}{\$408{,}513 + \$191{,}6881.2}$= 3.2 year = 3year

Payback Period Reference (PBP_{REFF})

$$PBP_{reee} = \frac{\text{Total fixed capital investment}}{\text{Total capital investment}} = \frac{\$1,916,881.2}{\$2,255,154.4} = 0.85$$

$PBP_{reff} = \frac{0.85}{0.12+0.85/10}$ where n = 10

$PBP_{reff} = \frac{0.85}{0.12+0.85/10} = 4.15$ this implies, the project is feasible because PBP is less than PBP_{reff}

That is $3 < 4.15$

Net present worth (NPW)

$NPW = \sum_1^{10}(1+i)^{-n}(NPj + dj + recj) - TCI$

Recovery =salvage value + working capital =0+338,273.2= $338,273.2

Annual cash flow(R) = NPjavg + djavg

= $408513 +$191,688.12 = $473,650.7

$P=\frac{R(1+i)^N-1}{i(1+i)^N}$ + recovery $((1+i)^{-N}$

$P=\frac{\$473,650.7(1+0.12)^{10}-1}{0.12(1+0.12)^{10}}$ + $338,273.2 $((1+0.12)^{-10}$, where i = mar = 12%

P = $2,546,740.7

Therefore, NPW= P– TCI = $2,546,740.7-$2,255,154.4 = $291,586.3

NPW = $291,586.3 since the value is positive the investment is acceptable and feasible

CHAPTER EIGHT

8. ENVIRONMENTAL IMPACT ASSESSMENT

8.1 Green House Emission

One of the major drivers of bio-fuel promotion worldwide is the concern about climate change and the potential of bio-fuels to reduce greenhouse gas (GHG) emissions. Although it is incontestable that the use of bio-ethanol is able to reduce GHG emissions significantly when compared to fossil fuels, assessments of quantified GHG reductions are useful and necessary. However, the GHG balance for bio-ethanol is highly variable and includes emissions of cultivation, transport, conversion process and distribution. Further, the GHG reduction potential depends on type of feedstock, agricultural practices, site productivity, and conversion technology and finally on the whole design of the study. Production of ethanol from sugarcane bagasse shows small GHG reductions with in some potential feedstock options. Using commercial processes, the use of ethanol derived from sugarcane bagasse, brings a 20% to 40% reduction in well to wheels CO_2 equivalent GHG emissions, compared to gasoline.

8.2 Toxic Exhaust Emissions

The major part of engine exhaust streams during ethanol combustion consists of the components nitrogen, carbon dioxide and water. All three components are non-toxic to human health. However, about 1.4% of petrol engine exhaust emissions are composed of more or less harmful substances to human health. Apart from the above mentioned emissions, fuel combustion emits particulate matter (PM), volatile organic compounds (VOCs), nitrogen oxides (NO_X), carbon monoxide (CO) and a variety of other toxic air pollutants. VOCs and NO_X are precursors for tropospheric ozone.

Momentary weather conditions and local geographic characteristics influence the impact of these air pollutants. Ozone formation example occurs more easily during hot weather. Also toxic air pollutants are more evident under hot weather conditions. They can be emitted either by the engine exhausts or by evaporation from fuel storage and fuel handling since ethanol has high volatile and generally increases evaporative emissions of gaseous hydrocarbons. As opposed to this, carbon monoxide is a larger problem in cold weather

and at high altitudes. To assess the environmental impact of substituting petrol with ethanol, both fuels have to be compared regarding their emissions. Harmful engine exhaust emissions from combustion of ethanol are generally lower when compared to the tailpipe emissions of fossil petrol. This ethanol can reduce certain vehicle pollutant emissions which exacerbate air quality problems, particularly in urban areas. Among the biggest benefits from using ethanol is the high reduction potential of carbon monoxide emissions. The use of E10 (ethanol mixture that contain 10% ethanol and 90% unleaded gasoline) is reported to achieve a 25% or greater reduction in carbon monoxide emissions due to the increased oxygen content of ethanol. Ethanol contains approximately 35% oxygen which promotes a more complete combustion of the fuel. Thus, in some countries, ethanol is used as oxygenate for fossil petrol and is increasingly replacing the oxygenate MTBE (methyl tertiary butyl ether) due to the high ground water contamination potential of MTBE. On the other hand ethanol-blended petrol emits higher evaporative hydrocarbons and other volatile organic compounds than petrol. When ethanol is added to gasoline, evaporative VOCs can increase due to the higher vapor pressure, measured as Reid vapor pressure of the ethanol mixture. Generally, adding the first few per cent of ethanol triggers the biggest increase in volatility. Raising the ethanol concentration further does not lead to significant further increases (and in fact leads to slight decreases), so that blends of 2%, 5%, 10% and more have a similar impact.

Impacts of ethanol on nitrogen oxides (NO_X) are generally minor and can either be increased or decreased, depending on conditions. NO_X emission from combustion of ethanol blends range from a 10% decrease to a 5% increase over emissions from gasoline. However, if the full life cycle of ethanol is considered, NO_X emissions can be significantly higher mainly due to emissions from feed stock production. NO_X is released from fertilizers used to grow bio-energy crops and is emitted mostly outside urban areas. When gasoline is blended with ethanol, emissions of most toxic air pollutants decrease. This is primarily due to the dilution effect of ethanol which substitutes some part of gasoline which emits toxic air pollutants. For instance, toxic emissions of benzene, 1, 3 butadiene, toluene and xylene decrease when ethanol is added. Benzene is a carcinogen, while olefins and some aromatics which are emitted by the combustion of fossil fuels as well are precursors to ground level ozone. While few studies have looked at the impacts on pollution levels from

high blends, it appears that impacts are similar to those from low blends. The above mentioned toxics benzene, 1, 3 butadiene, toluene and xylene which are emitted by the combustion of fossil fuels are considered to be more dangerous than emissions of ethanol combustion. During ethanol fuel combustion, emissions of the toxic air pollutants acetaldehyde, formaldehyde and peroxyacetyl nitrate (PAN) increase relative to straight gasoline. Acetaldehyde is emitted most but it is a less reactive and less toxic pollutant than formaldehyde. PAN is an eye irritant and is harmful to plants. No one of these pollutants is present in the unburned fuel, as they are only created as byproducts of incomplete combustion. Nevertheless, impacts of acetaldehyde and PAN seem to be minor as emissions are relatively low compared to other sources and as they can be efficiently removed by a vehicle's catalytic converter. Strict emissions control standards for cars and trucks will tend to mute the air quality impacts of bio-ethanol, since manufacturers are required to build vehicles that meet these standards under a range conditions.

CHAPTER NINE

9. CONCLUSION AND RECOMMENDATION

9.1 Conclusions

Hydrolysis of bagasse was carried out with dilute sulfuric acid and the optimum condition as well as interaction was examined during experiment, moisture content and sieve analysis was conducted for the raw material and different analytical and measured data was analyzed like, PH, density and odor were studied. Those all factors were significant variables for the yield of ethanol. Very high and low sulfuric acid concentration and temperature have negative effect on the yield of ethanol. Preparation of ethanol from sugarcane bagasse is feasible from the economic point of view in that its internal rate of return provides a return greater than the current rate of return. Moreover, the payback time is less than four years. Therefore, we concluded the preparation of ethanol from sugarcane bagasse is feasible according to the experiment result the economic evaluation studied, from the total capital investment, annual net revenue, net present worth and payback period result.

9.2 Recommendations

This project would like to suggest the following recommendations.

- During the experiment, doing there is a shortage of equipment and material used. For further improvement, those materials have to be fulfilled.
- The work is done with regard to ethanol preparation should not remain on paper and they should be implemented.
- To recommended that careful evaluation of the material balance and energy balance on preparation of ethanol from sugarcane bagasse process and study on fermentation starting conditions to determination the initial simple sugar and yeast concentrations.
- Detailed economic feasibility studies in the production process is recommended, since it is critical for the rationale of commercialization.

BIBLIOGRAPHY

[1]. Alfani, F.,Gallifuoco, A.,Saporosi, A., Spera, A., and Cantarella, M... (2000). Comparison of SHF and SSF processes for the bioconversion of steam-exploded wheat straw. Journal of Industrial Microbiology and Biotechnolgy 184-192.

[2]. Badger, P.C. (2002), Ethanol from cellulose: a general review. In: Trends in new crops and new uses. Eds. Janick, J., Whipkey, A. ASHS Press, Alexandria, VA., pp. 17-21.

[3]. BAFF (BioAlcohol Fuel Foundation) (2006), www.baff.infoAccessed in July 2006.

[4]. Balat,M. (2011). Production of bioethanol from Lignocellulosic materials via the biochemical pathway: A review. Energy Conversion and Management, Vol. 52, No. 2, pp. 858-875, ISSN 0196-8904.

[5]. Brandberg,T.(2005) Fermentation of undetoxified dilute acid lignocellulose hydrolysate for fuel ethanol production. Doctoral dissertation, Chalmers University of Technology, Göteborg, Sweden.

[6]. Berg, Christoph, World Ethanol Production 2001, F. O. Licht, July 2001.

[7]. BioSource Technology- Dawson and Bhoopathy, Vol.77 April 2002.Use of Post-Harvest Sugarcane Residue for Ethanol Production.

[8]. Camacho, F., González-Tello, P., Jurado, E., and Robles, A.1996 Microcrystalline-cellulose hydrolysis with concentrated sulphuric acid. J. Chem. Tech. Biotechnology. 67:350-356.

[9]. Cellulosic Ethanol-Wikipedia, The Free Encyclopedia. Lignocellulose Biomass Processing: A Perspective by Michael K., And Mohammed M., retrieved on October 2012.

[10]. DiPardo, J. (2000), Outlook for biomass ethanol production and demand, Washington, DC: U.S. Department of Energy, Energy Information Administration.

[11]. Dunn, C. (1959). Industrial Microbiology. Third edition, London pp 763.

[12]. Demirbas, A. (2005). Bioethanol from Cellulosic Materials: A Renewable Motor Fuel from Biomass. Energy Sources 27: 327-337.

[13]. Gebreegziabher Z., Mekonnen A., Ferede T., and Köhlin G., 2014. Profitability of biofuels production the case of Ethiopia. Environment for Develop

[14]. Harinen, S.,(2004), Analysis of The Top Phase Fraction of Wood Pyrolysis Liquids, Master‟ Thesis, Laboratory of Applied Chemistry, Department of Chemistry, University of Jyvaskyla.

[15]. Hsu,T. A.; Ladisch, M. R. and Tsao, G. T.(1980). Alcohol from cellulose.Chem. Technol., 10(5), 315–319

[16]. Hamelinck, C.N., van Hooijdonk, G., and Faaij, A.PC.**(**2005). Ethanol from Lignocellulosic biomass: techno-economic performance in short-, middle- and long-term. Biomass and Bioenergy p 384–410.

[17]. Holtzapple, M.T. and A.E. Humphrey, (1984). "The effect of Organosolv Pretreatment on the enzymatic hydrolysis of Poplar." Bioethanol Bioeng 26(7) 670-676.

[18]. Izmirlioglu G. and Demirci A., 2012. Ethanol production from sugarcane bagasse by using saccharomyces cerevisiae. MDPI - Open Access Publishing, 2, 738-753.

[19]. J. ML Coulson, J. F. Richardson, 1990.working principle of distillation, volume 6, 7th ed, 1990.

[20]. Jordbruksverket (2006), Marknadsöversikt: Etanol, en jordbruks- och industri produkt.

Rapport 2006:11

[21]. Laser, M., Schulman, D., Allen, S.G., Lichwa, J., Antal, M.J., and Lynd, L.R., (2002). A comparison of liquid hot water and steam pretreatments of sugar cane bagasse bioconversion to ethanol, Bio-resource Technology 81, 33–44.

[22]. Lin, Y., Tanaka, S. (2006) Ethanol fermentation from biomass resources: current state and prospects. Appl. Microbial. Biotechnol. 69, 627-642

[23]. Long beach CA. Phillips M.2004, Ethanol for a sustainable fuel energy future.

Science,315:808-810.

[24]. Mosier, Ce., Wyman, B.d., Dale, R.T., Elander, Y.Y., Lee, M. Holtzapple, and C.M., Ladisch, (2005). Features of promising technologies for pretreatment of Lingo-cellulosic Biomass. Bio-resource Technology, 966, 0960-8524.

[25]. Mussatto S. I.,and Teixeira J. A. (2010); Lignocellulose as raw material in fermentation processes, IBB – Institute for Biotechnology and Bio-Engineering, Centre of Biological Engineering, University of Minho, Campus de Gualtar, 4710–057 Braga, Portugal.

[26]. Nirbhay Gupta, 2008. Hydrolysis of Lignocellulosic Materials for Ethanol production, National Institute of Technology, Rourkela.

[27]. Prasad, S., et al., 2007. Ethanol as an alternative fuel from agricultural, industrial and urban residues. Resources Conservation and Recycling 50: 1-39.

[28]. Process Biochemistry, Volume 32, Issue 8, May 2002.

[29]. Sun, Y., Cheng, J. (2002) Hydrolysis of lignocellulosic materials for ethanol production: A review. Bioresource Technol., 83, 1-11.

[30]. Taherzadeh, M. J., and Karimi, K., 2007. Acid-Based Hydrolysis Processes for Ethanol from Lignocellulosic Materials: A Review. Bio Resources Vol 2: 472-499.

[31]. Tian S., Wang X., Zhao R. and Ma S., 2015. Effect of doping pretreated corn stover conditions on yield of bioethanol in immobilized cell systems.

[32]. www.mache.com/equipment cost.

[33]. Yacob G.,2013.Long term bioethanol shifts and transport fuel substation in Ethiopia status prospects, and implications.

[34]. Yang B, Wyman CE (2008) Pretreatment: the key to unlocking low cost cellulosic ethanol.

[35]. Zhao X, Cheng K, Liu D. (2009). “Organosolv Pretreatment of Lignocellulosic Biomass for enzymatic hydrolysis.” Appl Microbiol Bioethanol 82(5): 815-827.

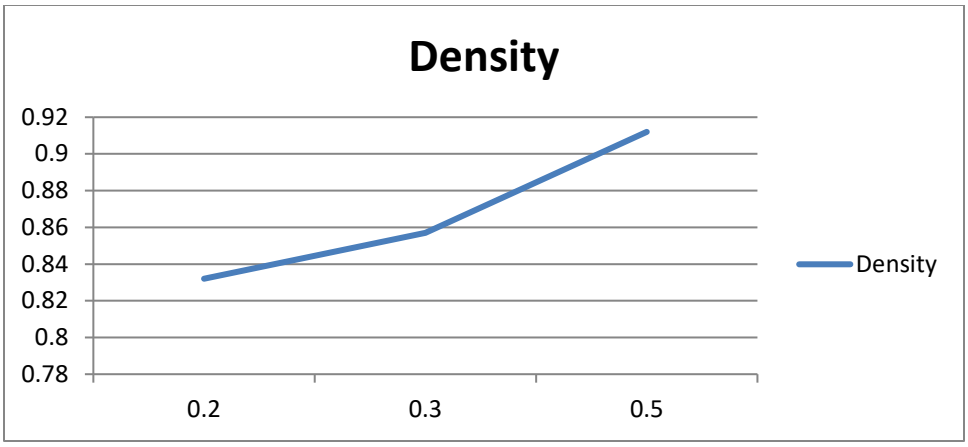
APPENDIX

Appendix A: Figures

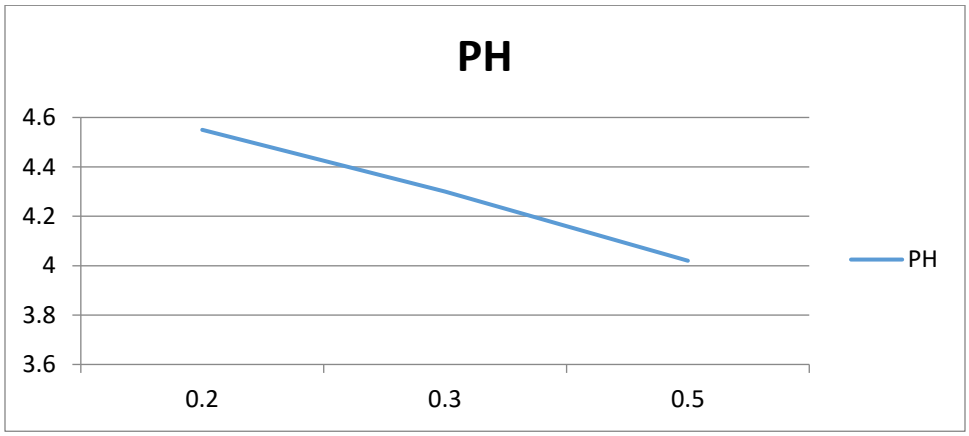
Sugarcane bagasse sample

Grinded bagasse

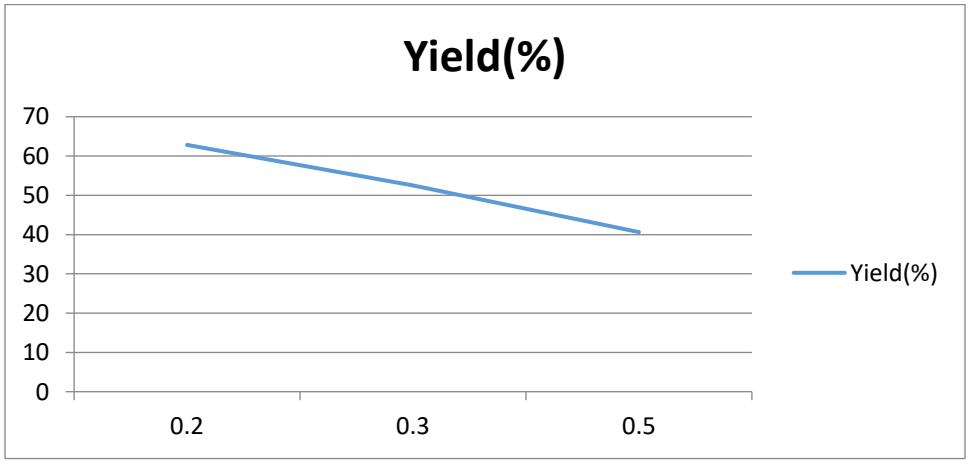
Sieved



Concentration of sulfuric acid versus density of ethanol



Concentration of sulfuric acid versus PH of ethanol



Concentration of sulfuric acid versus yield (%) of ethanol

Appendix B: Tables

Physical properties

Taste	Sweet
Crystal	Monoclinic
Specific gravity at 20 ^{0}C	1.05917
Optical activity	Dextro-rotatory

Chemical properties

Action of heat	Perfectly dry sugar can be heated to 160^{o}C without decomposition. It then melts forming a non-crystallizing substance. In the presence of moisture it decomposes at 100^{o}C, becoming a caramel and liberating water. On further heating changes to Co_2 and formic acid.
Action of heat on dilute solutions	By prolonged heating at the boiling point the dissolved sucrose slowly combines with water and breaks up into glucose and fructose.

Chemical composition of bagasse

Composition	Contents (%)
Cellulose	50
Hemicellulose	22.5
Lignin	21
Ash	2.5
Waxes	Less than 1