WOLKITE UNIVERSIY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

PRODUCTION OF BIOETHANOL FROM TEFF HUSK

This project is submitted to the School of under Graduate Studies of Wolkite University, in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in the Department of Chemical Engineering (Process Engineering Stream)

Advisor: Mr. Fentahun T.

Done By:

1. **Muluget Bezawork ……………………ENGR/661/08**
2. **Nega Tekle…………………………….. ENGR/697/08**
3. **Rediet Ayana………………………….. ENGR/728/08**
4. **Temeche Wanaw……………………….ENGR/851/08**
5. **Wondmu Gebre………………………...ENGR/923/08**

DECEMBER 4, 2013

WOLKITE, ETHIOPIA

Declaration

We hereby declare that the thesis is based on our original work except for flotation and citations which have been duly acknowledge. We also declare that the paper previously or currently has not been submitted for any other department at Wolkite University.

Prepared by:

Name:	ID No:	Signatures:
1. Muluget Bezawork	ENGR/661/08	_____________
2. Nega Tekle	ENR/697/08	_____________
3. Rediet Ayana	ENGR/728/08	_____________
4. Temeche Wanaw	ENGR/851/08	_____________
5. Wondmu Gebre	ENGR/923/08	_____________

This thesis has been submitted for examination with my approval as University

Advisor Name: Mr. Fentahun. T Signature: _________

Examiner: _____________ Signature _____________

Chairperson: _____________ Signature _____________

Project Organizer _____________ Signature _____________

ABSTRACT

Biofuels are alternatives to fossil fuels to ensure energy security and mitigate climate change. Currently, most biofuel is in the form of bioethanol generated from starch or sugar. Conversion of cellulosic biomass, which is both abundant and renewable, to bioethanol is a promising alternative. The objective of this work is to evaluate the feasibility of bio ethanol production from teff husk by using commercial bakery yeast, i.e., *S. cerevisiae*. To conduct this study, fermentation was held at temperature 30 °C and at varies pH, and treated using different acid concentrations and residence times. Teff husk hydrolyzed by refluxing, a solid to liquid ratio of 1:10, using dilute sulfuric acid (0.5, 2.25 and 4 %) and distilled water at hydrolysis time of 30 min and soak for 24 hours keeping boiling at temperature of 100 ^{0} c. Based on these hydrolysis results, fermentation process is performed. In the process, it is observed that bio ethanol concentration decreased with an increase in acid concentration, hydrolysis time and fermentation time. The final result is obtained with fermentation and distillation process. Under these conditions maximum bio ethanol concentration production 51.35%, a satisfactory result as compared with literature data. The result indicated that being available in plentiful amounts, teff husk is potential feedstock for bioethanol production in Ethiopia.

ACKNOWLEDGEMENT

We would like to thank the Almighty GOD for giving us the strength and wisdom to successfully complete this project paper for his protection and strength, and an ever present helps in the entire Situation and challenge that we face. Moreover, we would like to express our heartfelt appreciation and thank to our advisor Mr. Fentahun for his sustainable and appreciable guidance, advising, for sharing his Knowledge, skill, experience and fine-tuning up to the successful Completion of this project. We would also like to thank the Chemical Engineering Laboratory staff members for technical support during the laboratory demonstration.

We also really want to appreciate our group members for contributing their individual responsibilities and support in terms of completing this study. Finally, we acknowledge our family with the deepest gratitude who encouraged us to strive toward academic-excellence and always wish the best for them.

List of Table

List of Figure

List of Acronym

TVA	Tennessee Valley Authority
MTBE	Methyl tertiary butyl ether
FPL	Forest Products Laboratory
SHF	Separate Hydrolysis and Fermentation
CBP	Consolidated Bio-Processing
SHF	Separate Hydrolysis and Fermentation
SSFS	Simultaneous Scarification and Fermentation
EtOH	Ethanol
DRS	Dry residual solid

Table of Contents

Chapter One

1. Introduction

1.1. Background

Renewable energy is now capturing a good share of the worldwide headlines because of concerns about declining Supplies of fossil fuels, and the ever-increasing demand for fuels. Over the world, governments have encouraged the use of alternative sources of energy to overcome energy crisis problems. The Higher price of oil has attracted greater attention to biofuels, especially Bioethanol, biodiesel, bio hydrogen, and so on. Biofuels may be classified under the categories of first or second-generation biofuels First-generation biofuels are generally made from carbohydrates, lipids, and oils or agro-industrial wastes using conventional technologies. Second-generation biofuels are generally derived from lignocelluloses biomass including Cellulosic plant biomass such as the stalks, stems, wood (Izmirlioglu, 2014).

Bioethanol is clear, colorless liquid, biodegradable and nontoxic. Bioethanol production from renewable sources to be used in transportation is now an increasing demand worldwide due to continuous depletion of fossil, economic and political, crises and growing concern on environmental safety. Mainly three types of raw materials that is sugar juice, starchy crops, and lignocelluloses material, are being used for this purpose.

Today, biomass covers the large presence of the world’s primary energy demand. Against the rising of crude oil prices, depletion of resources, political instability in producing countries and environmental challenges, biomass has high potential to replace the supply of an energy-hungry civilization all over the world. At the current level of production and consumption, the world are going to run out of non-renewable energy produced from fossil fuels (coal, crude oil(petroleum), natural gas), and it is too difficult to meet the need for our future generation. Thus, our countries have to invest in renewable energy options, to have sustainable energy. At present, sugar, and starch-based raw materials like cereal, grains are used for the production of Bioethanol (Tech, 2014).

However, it is obvious that Ethiopia has a scarcity of food; hence using Cereal, grains for Bioethanol production, which is commonly done in other biofuel promoting countries like Europe and the USA is difficult. So, the available sources are biomass which is an abundant and renewable source of energy-rich carbohydrates, which can be efficiently converted by microbes into biofuels of which, Bioethanol is widely produced on an industrial scale today these available.

Teff (Eragrostis tef) is an ancient tropical cereal that has its center of origin and diversity in the northern Ethiopian highlands from where it is believed to have been domesticated. Teff is a minor cereal crop worldwide, whereas, in Ethiopia, it is a major food grain, mainly used to make injera, a traditional fermented Ethiopian pancake. In other countries like Australia, South Africa, and the United States, it is principally used as a forage crop for animal feed (Baye, 2014). So, in Ethiopia, while harvesting, the seed and chid (gleba) were separated from each and taken to their respective storeroom. However, the husk was simply disposed there on the land, and eaten by cattle. Even though this husk is used as cattle feed, since the demand for fuel and resource to produce these fuels are unbalanced it is better if we will used it for biofuel (Bioethanol) production. Because, in addition to this product we can produce more proteinase cattle feed, which is called DRS as by-product.

1.2. Statement of the problem

Due to the steeply decrease in fossil fuels, the issue of having sustainable energy is the headache of the world. Because, If the consumption rate of fossil fuels(coal, crude oil(petroleum), natural gas) is continuing as such , there will be no resources for the future generation to produce energy. Not only this but also, the surrounding environment will be destroyed, because while mining, and using these fossil fuels they release a high amount of pollutants like (CO_2, SO_2, NO_2, so on) to the atmosphere.

Nowadays, this idea has initiated the governments and researchers to look for other alternative renewable energy sources that are technically feasible, economically competitive and environmentally friendly. Among these available alternative energy resources, a biofuel derived from different biomass, have been gaining attention as a replacement for fossil fuels. Hence, we have selected to produce Bioethanol, because, it is an important biofuel which can be produced from different types of biomass, and save our countries from importing of different fuels in some extent. Having this idea in mind, since teff husk, which enables us to obtain Bioethanol product is available in our countries in a good manner, we are eager to do our proposal on Bioethanol production from it, which provides a sustainable energy that enables the present demands to meet their need, and also future generation.

1.3. Objectives

1.3.1. General objective

The general objective of this thesis project is to produce bioethanol as a sustainable energy option from **teff husk** biomass by fermentation using yeast (Saccharomyces cerevisiae).

1.3.2. Specific objectives

- To collect and characterize teff husk biomass from farm
- To convert polysaccharide into monosaccharide by Acid hydrolysis
- To determine the effect of parameters on hydrolysis and fermentation process.

1.4. Scope of the study

This thesis project work involves the collection of teff husk from sources (farm), grinding, hydrolyzing, and fermenting followed by distillation. The effect of concentration of acid on hydrolysis process, and the effect of some process parameters like PH, retention time on fermentation is done. The process includes the physical and chemical characterization teff husk.

1.5. Significance of the study

This study has a high contribution to the substitution of fossil fuel by biofuel. Because it uses renewable biomass to overcome the problems raised from the depilation of fossil fuels. Additionally, it has no direct conflict with human food, as the case of first generation biofuels production. Not only this but also, this study provides sustainable energy for the next-generation which enables them to meet their need, and promote the agricultural lead industrialization strategy in Ethiopia.

Chapter Two

2. Literature Review

Bio-fuels: - are alcohols, ethers, esters and other chemicals made from cellulose-based biomass. This includes herbaceous and woody plant, agricultural and forestry residues and a large portion of municipal and industrial waste materials. Bio-fuels are renewable since they are produced from biomass organic matter, such as plants. The biofuels industry has evolved from using first generation feedstock (typically food crops) to using second and third generation feed stocks, for both ethanol and biodiesel. While the term bio-fuels denote any fuel made from biological sources, for most practical uses, the term refers to either ethanol or biodiesel. The last few years have seen tremendous growth in biofuels (Wondale, 2012).

Biodiesel: - is an ester that can be made from several types of oils, such as vegetable oils and animal fats. Biodiesel is typically used as a blend of 20 percent biodiesel and 80 percent petroleum diesel called B20. B20 can be used in a conventional diesel engine with essentially no engine modifications. There is also a growing interest in using biodiesel where workers are exposed to diesel exhaust, in aircraft to control local pollution near airports, and in locomotives that face restricted use unless emissions can be reduced (Wondale, 2012).

Alcohol: - The word alcohol derives from Arabic al-kuhul, which denotes a fine powder of antimony produced by distilling antimony and used as eye makeup. Alcohol originally referred to any fine powder, but medieval alchemists later applied the term to the refined products of distillation, and this led to the current usage. Ethanol, the most widely used biofuel, is made in a process similar to brewing beer. It is blended with gasoline to improve vehicle performance and reduce Air pollution. Ethanol is a clean-burning, high-octane fuel that is produced from renewable sources. Ethanol is beginning to be used all around the world as a transportation fuel, and it has some distinct advantages. Fuels that burn too quickly makes the engine "knock", a characteristic rattling sound. The higher the octane rating, the slower the fuel burns, and the less likely the engine will knock. When ethanol is blended with gasoline, the octane rating of petrol goes up by three full points, without using harmful additives. Similar to the case of biodiesel, adding ethanol to gasoline "oxygenates" the fuel.

2.1. History of Fuel Bioethanol

The use of ethanol as an automobile fuel is not a new invention. Already in 1908, Ford's model could be adjusted to run on either gasoline or alcohol. However, after World War II the interest in using ethanol as fuel declined because cheap gasoline made from petroleum was available. In the 1970s, the interest in fuel ethanol was renewed due to the oil crisis. 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 in the 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 (F.O. Licht's World ethanol and biofuels report 2006; 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 (Wondale, 2012).

About 99% of 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 years, the USA has increased its production and today both countries have an annual production of about 16 000 000 m3 (F.O. Licht's World ethanol and biofuels report, 2006). 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. Ethanol Besides, 4, 000, 000 automobiles drive on a blend of 95% ethanol and 5% water. In the 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.

In Sweden, ordinary gasoline typically contains 5% ethanol and the number of flex-fuel automobiles is increasing ('Amhare, 2016). 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 future national ethanol production. In 2004 an ethanol-from-lignocelluloses pilot plant was inaugurated in the city of Örnsköldsvik. Agro-ethanol plans to expand its production of ethanol from grain with 150, 000 m3in 2008(Wondale, 2012).

2.2. Bioethanol and its Application

Ethanol is an important chemical product with emerging potential as a biofuel to replace fossil fuel. An eco-friendly Bioethanol is one of the alternative fuels that can be used unmodified petrol engines with current fueling infrastructure and it is easily applicable in present combustion engines as mixing with gasoline (Hansen et al., 1985). Ethanol produced by microbial fermentation of biomass is used primarily as a substitute for gasoline, usually blended, although it can also be used on its own commonly include industrial use or rocket fuel. In developing countries, it is also commonly used to replace kerosene for cooking and illumination. Besides being a renewable energy source, Bioethanol has other advantages over fossil fuels: it emits less CO_2 when burned (Brown et al., 1998), which also is compensated by CO_2 uptake from the biomass; it does not emit toxic gases (such as CO and nitrate oxides) or particles when burned; less energy is required to produce ethanol than the equivalent amount of gasoline; it is rapidly biodegraded in the environment; it has a higher octane rating than gasoline (Amhare, 2016).

2.3. World Market of Ethanol

Today, bio-ethanol is the most dominant bio-fuel and its global production showed an upward trend over the last 25 years with a sharp increase from 2000. As of 2005, worldwide production capacity for bio-ethanol fuel was about 45 billion liters per year, with approximately 15% annual growth between 2000 and 2005. This value increased to 49 billion liters in 2006, when the Americans produced 75% of the total world ethanol output, followed by Asia/Pacific and Europe/Africa with respective values of 15 and 10% (Licht, 2006). The industrial alcohol market showed a rather modest rate of growth similar to the increase in Gross Domestic Product in many countries. The market for beverage alcohol in most developed countries is stagnating, due to increased health awareness.

Fuel ethanol production is predicted to have the strongest increase in the Americans, where the production is expected to rise to around 75 billion liters by 2015, representing about 42 billion liters increase in the projection period. In Asia, this value is anticipated to increase to 8 billion liters during the same period, and in Europe, with the policy of increasing the share of biofuels in the transportation sector, the production will rise strongly. Therefore, the total output in 2015 is forecast to reach over 115 billion liters (Amhare, 2016).

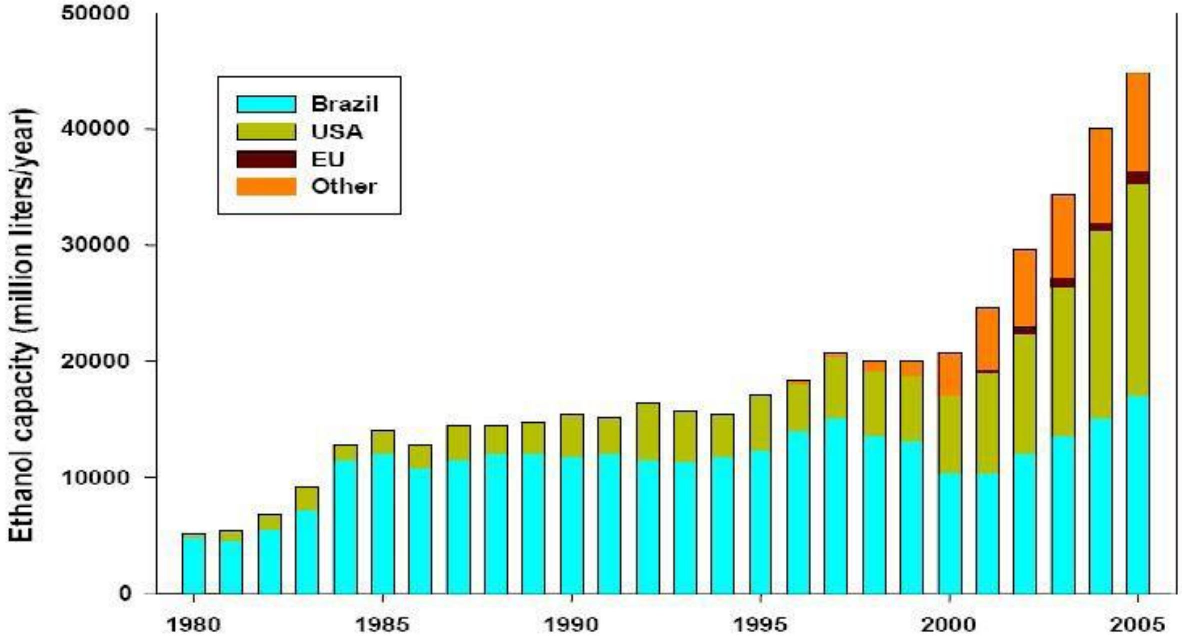


Figure 2.1.Annual ethanol production by the major producers, adapted from Mabee (2007)

2.4. Current Ethanol production in Ethiopia

Bioethanol is manufactured from the microbial conversion of biomass material through fermentation. The production process consists of the conversion of biomass to fermentable sugars, fermentation of sugar to ethanol and the separation and purification of ethanol. Fermentation initially produces ethanol containing a substantial amount of water. Then this solution is distilled using the distillation column the majority of water to yield up to 95 percent purity ethanol, the balance being water. This mixture is called hydrous ethanol. If the remaining water is removed in further process, the ethanol is called anhydrous ethanol and suitable for blending with gasoline. Ethanol is “denatured “before leaving the plant to make it unfit for human consumption by the addition of a small amount of products such as gasoline (ESDA, 2005). The worldwide recent awareness for the use of ethanol to replace petroleum and generation of power along with sugar mill plants should have led to setting up of a number of ethanol plants and co-generations. Ethiopia has several sugar real estate (Finch, Methara, and Wonji Shoa) industries that are run and administered by Sugar Development Agency. Among molasses derived products, ethanol takes the largest part, but its utilization must attract the attention of the government policymakers to utilize as bioethanol. Bioethanol or biofuel is ethanol based products that can process into liquid fuels for transport purposes (Amhare, 2016).

S. Industry	2009/10	2010/11	2011/12	2012/13	2013/14
Fincha	6.9	13.2	15.7	17.1	21.5
Methara	8.9	12.8	17.5	21.3	21.3
Wonij	-	-	10.6	10.6	10.6
Tendaho	-	15.9	30.1	43.6	55.4
Total	15.8	41.9	73.9	92.6	108.8

Table 2.1 Projected Ethanol Production by year in millions, Liter. (Source: Ethiopian Sugar Agency, 2009).

2.5. Teff for Human Consumption

Teff is cultivated in a few countries such as South Africa, India, USA, Eritrea, and Ethiopia, although it is primarily used for human consumption only in the latter two. Although teff has been used for food in Ethiopia for many centuries, it is only recently that its use as a food ingredient has gained interest in other parts of the world.

As technological challenges are overcome in processing teff to make bread and other food products, the demand for teff is likely to increase globally (Baye, 2014).

2.6. Consumption of teff in Ethiopia

In the past, a major determinant of grain consumption was its production. However, with the improvement in market linkages, this picture is gradually changing. In Oromia region, for instance, where regional teff production is the second highest next to Amhara region in Ethiopia, its consumption expenditure is only 8 percent In contrast, the Afar region, little known for its teff production, has comparatively higher teff consumption expenditure (10 percent) Today, several factors including agro-ecology, livelihoods, and income determine cereal consumption in Ethiopia. Findings from the analyses of a nationally representative household consumption and income survey conducted in 2004/05, suggests that teff’s contribution to energy (calorie) intake in Ethiopia is only 11 percent Maize (17 percent), sorghum (14 percent) and wheat (13 percent) are all more important sources of calories in Ethiopia. This finding on consumption challenges assumptions that teff is a major staple in Ethiopia that are based solely on production figures (Baye, 2014).

Teff is possibly the smallest cereal grain with an average length of ~ 1 mm The average thousand kernel weight of 12 teff varieties tested) was 0.264 g. The minuteness of teff grains has nutritional and technological implications. For instance, as teff grains are difficult to decorticate, the cereal is consumed as a whole grain, improving nutrient intake for consumers. The color of teff can vary from white (ivory) to dark brown (black) depending on the variety. In Ethiopia, three major categories can be identified: white (**nech**), red (**quey**) and mixed (**sergegna**). It is also common for wholesalers to further sub-divide white teff into very white (**magna**) and white (**nech**). However, given that these classifications are imprecise and subjective, what may be referred to as magna by some may be considered as nech by others. White teff generally grows only in the Ethiopian highlands and require relatively good growing conditions. This, along with its higher consumer preference, may justify why white teff is the most expensive type of teff. However, in recent years, red teff, which is believed to be more nutritious, is also gaining popularity among health-conscious consumers in Ethiopia (Baye, 2014).

2.7. Feedstock for Bioethanol Production

Almost any plant-based material can be the feedstock for Bioethanol production. All plants contain sugars, and these sugars can be fermented to make ethanol in a process called a biochemical conversion. Plant material also can be converted to ethanol using heat and chemicals in a process called thermochemical conversion. Some plants are easier to process into ethanol than others. Some require few resources to grow, while others need intensive care. Some are used for food as well as fuel, while others are cultivated exclusively for ethanol; even plant based wastes can become bioethanol.

Climate and soil types determine the types and amounts of plants that can be grown in different geographic areas. Another important consideration is feedstock logistics is the steps necessary to move feedstock from fields or collection areas to ethanol production plants. For agricultural and forestry feedstock, these steps include harvesting, transportation, storage, and preprocessing (Cellulosic Ethanol, 2010).

The use of ethanol as an alternative motor fuel has been steadily increasing around the world for several reasons. Domestic production and use of ethanol for fuel can decrease dependence on foreign oil, reduce trade deficits, create jobs in rural areas, reduce air pollution, and reduce global climate change carbon dioxide buildup. Ethanol, unlike gasoline, is an oxygenated fuel that contains 35% oxygen, which reduces particulate and NOx although fungi, bacteria, and yeast microorganisms can be used for fermentation, specific yeast (Saccharomyces cerevisiae also known as Bakers' yeast, since it is commonly used in the backing industry) is frequently used to ferment glucose to ethanol. Theoretically, 100 grams of glucose will produce 51.4 g of ethanol and 48.8 g of carbon dioxide. However, in practice, the microorganisms use some of the glucose for growth and the actual yield is less than 100% other emissions from combustion. The following are different type's feedstock for ethanol production (Cellulosic Ethanol, 2010).

2.7.1. Sugar

This is the oldest and simple feedstock for ethanol production. Fermentation involves microorganisms that use the fermentable sugars for food and in the process produce ethanol and other byproducts. These microorganisms can typically use the 6-carbon sugars, one of the most common being glucose. Therefore, biomass materials containing high levels of glucose or precursors to glucose are the easiest to convert to ethanol. However, since sugar materials are in the human food chain, these materials are usually too expensive to use for ethanol production (J. Janick and P.C. Badger, 2002). One example of a sugar feedstock is sugarcane. Brazil developed a successful fuel ethanol program from sugarcane for several reasons: (1) Brazil conventionally relied heavily on imported oil for transportation fuels, which caused a severe economic drain on the country; (2) Brazil can attain very high yields of sugarcane; and (3) Brazil has also experienced periods of poor sugar markets. As a result, the Brazilian government established programs supportive of the industry with the result that Brazil has been able to successfully produce and use sugarcane for fuel ethanol production (J. Janick and P.C. Badger, 2002).

Biomass feedstock's rich in sugars include sugar beet, sweet sorghum, and various fruits. However, these materials are all in the human food chain and, except for some processing, residues are generally too expensive to use for fuel ethanol production (Amhare, 2016).

2.7.2. Starch

Another potential ethanol feedstock is starch. Starch molecules are made up of long chains of glucose molecules. Thus, starchy materials can also be fermented after breaking starch molecules into simple glucose molecules. Examples of starchy materials commonly used around the world for ethanol production include cereal grains, potato, sweet potato, and cassava. Cereal grains commonly used in the US for ethanol production include maize and wheat. Starchy materials require a reaction of starch with water (hydrolysis) to break down the starch into fermentable sugars (saccharification). Typically, hydrolysis is performed by mixing the starch with water to form a slurry which is then stirred and heated to rupture the cell walls. Specific enzymes that will break the chemical bonds are added at various times during the heating cycle (J. Janick and P.C.

Badger, 2002).

2.7.3. Cellulosic

Like sugar materials, starch materials are also in the human food chain and are thus expensive. Fortunately, another alternative exists that is cellulosic material. Examples of cellulosic materials are paper, cardboard, wood, and other fibrous plant 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 feedstock for ethanol production (P.C. Badger, 2002). The global production of plant biomass, with over 90% lignocelluloses content, is estimated to be about 2×10^{11}tons/year, where about 8-20$\times10^{9}$

Cellulose: - is a linear polymer of D-glucose units linked by β-1, 4-linked glucose. Cellulose molecules are completely linear and have a strong tendency to form intramolecular and intermolecular hydrogen bonds. Bundles of cellulose molecules are thus aggregated together in the form of micro-fibrils, in which highly ordered (crystalline) regions alternate with less ordered (amorphous) regions. The crystalline region in which the linear molecules of cellulose are tons of primary biomass remain potentially accessible annually (Lin and Tanaka, 2006). Over the last few decades, extensive attention has been devoted to research on the conversion of lignocelluloses materials to ethanol.

Lignocelluloses are complex mixtures of carbohydrate polymers, namely cellulose, hemicelluloses, lignin, and a small number of compounds known as extractives (Prasad et al., 2007). The second-generation ethanol feedstock primarily comprises feedstock called cellulosic Feedstock. In the case of these feed stocks, ethanol is derived not from the starch component, but the lignocelluloses component of the feedstock. A large number of non-food wild plants that grow in non-cultivated and non-arable lands, and even plant waste, contain lignocelluloses; as a result, the second generation ethanol feed stocks overcome the two main bottlenecks for the first generation feedstock: adversely effects on food prices, and inability to scale (P.C. Badger, 2002).

Bonded laterally by hydrogen bonds is characterized by the cellulose lattice which extends over the entire cross-section of the micro-fibrils. This crystalline region is bounded by a layer of cellulose molecules that exhibit various degrees of parallelism. The less ordered region is called the Para-crystalline or amorphous region. The disordered region allows the disintegration of the cellulose by hydrolysis into rod-like particles with aqueous, non-swelling, strong acid. Micro fibrils build up fibrils and finally cellulose fibers. As a consequence of its fibrous structure and strong hydrogen bonds cellulose has high tensile strength and is insoluble in most solvents. The orientation of the linkages and additional hydrogen bonding makes the polymer rigid and difficult to break (Alemayehu, 2015)

The molecular arrangement of this fibrillar bundle is sufficiently regular that cellulose exhibits a crystalline X-ray diffraction pattern. Typically, cellulose chains in primary plant cell walls have degrees of polymerization in the range of 5,000 to 7,500 glucose monomer units, with the degree of polymerization of cellulose from wood being around 10,000 and around 15,000 from cellulose cotton. The basic repeating unit of cellulose is cellobiose. Under normal conditions, cellulose is extremely insoluble in water, which is, of course, necessary for it to function properly as the structural framework in plant cell walls (‘Amhare, 2016).

Hemicelluloses: were originally believed to be intermediates in the biosynthesis of cellulose. Today it is known, however, that hemicelluloses belong to a group of heterogeneous polysaccharides that are formed through biosynthetic routes different from that of cellulose. In contrast to cellulose which is a homo-polysaccharide, hemicelluloses are hetero-polysaccharides. Hemicelluloses are heterogeneous polymers of pentose (xylose, arabinose), hexoses (mannose, glucose, galactose), and sugar acids.

They are generally cataloged according to the main sugar residue in the backbone, e.g., xylans, mannans, and glucane, with xylans and mannans being the most common. Hemicelluloses, because of its branched, amorphous nature, are relatively easy to hydrolyze. Some hemicelluloses contain mostly xylan, whereas others contain mostly glucomannans. Among softwood hemicelluloses, there are galactogluco mannans, arabinoglucuron oxylan, and arabinogalactan, meanwhile hardwood hemicelluloses comprises mainly glucuronoxylans and glucomannan (‘Amhare, 2016)

Lignin: is a complex, hydrophobic, cross-linked, three-dimensional aromatic polymer of phenyl propane building blocks. The mechanical strength properties of plants are mainly due to the incorporation of lignin into their cell walls, whereby huge plants such as trees can remain upright. P-coumaryl alcohol (I), coniferyl alcohol (II) and sinapyl alcohol (III) are the primary precursors and building units of all lignin. Lignin is one of the most complicated natural polymers for its structure and heterogeneity, which makes it extremely resistant to chemical and biological degradation (Lee, 1997).

The husk of any cereal grains like wheat, rice, barley is lignocellulosic materials, so Teff husk is one of lignocellulosic material, which can be used for Bioethanol production. While the harvesting of this teff, the farmers take their seed as the desired product and take the chid part to the other side for a different purposes. However, a large amount of teff husk is disposed there on the land, and some part is eaten by cattle’s, and the left is deteriorated and destroyed there. So, since there are abundant resources of this feedstock in our country, we have selected this husk as feedstock for Bioethanol production. Physio-chemical characteristics of teff husk powder

Property	husk powder
Bulk density (g/cm^3)	0.4225
Ash content (%)	7
Specific surface area (m^2/g)	263
PH	7.41

Table 2.2.Physio-chemical parameters of teff husk powder (Yassin, 2017)

2.8. Bioethanol production process

Bioethanol can be produced, by fermentation of sugar-containing feeds, starchy feed materials or lignocelluloses materials. The two primary ways of producing fuel ethanol from cellulosic feedstock are: Biochemical conversion process and Thermochemical conversion process (Cellulosic ethanol, 2010), however, researchers are also exploring photo biochemical conversion process.

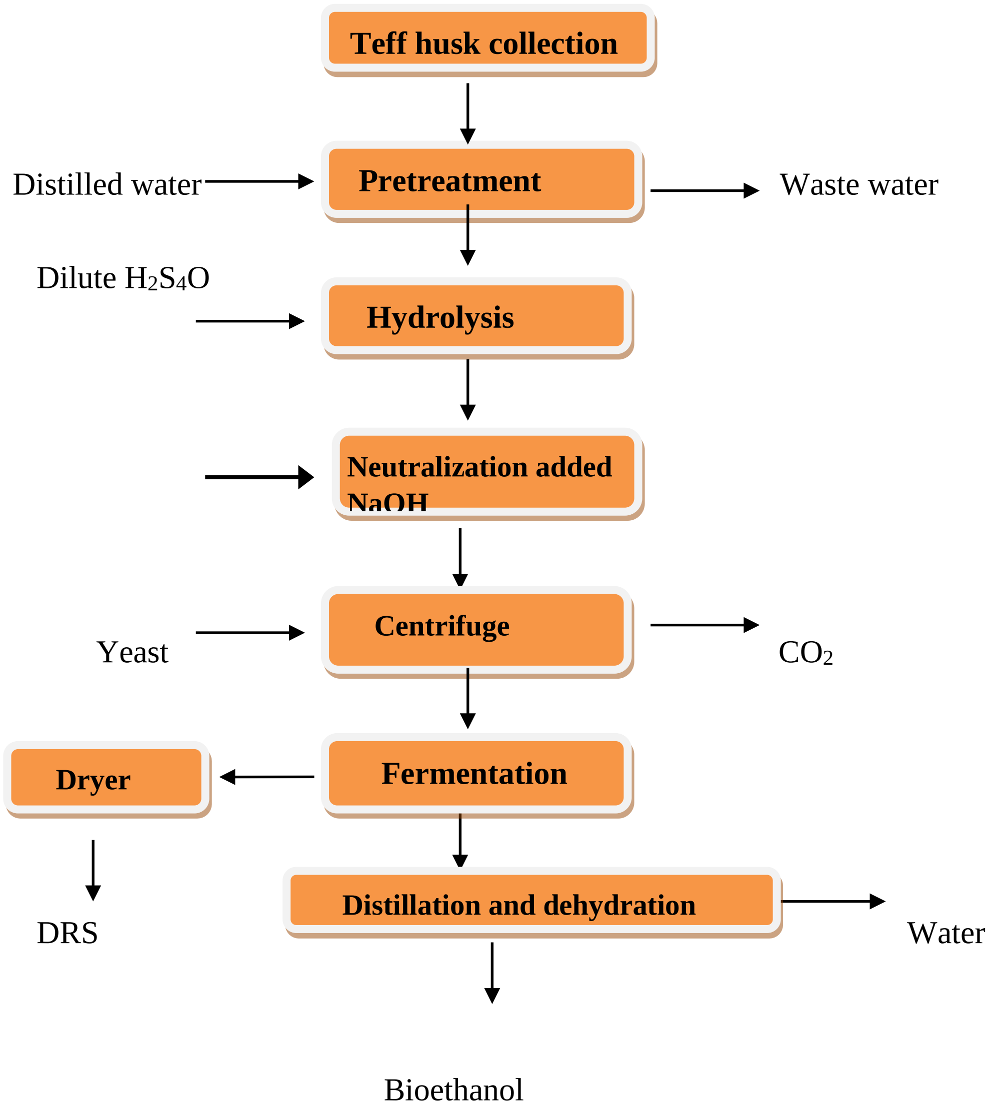


Figure 2.2 Block flow diagram bioethanol production from teff husk

2.8.1. Biochemical conversion process

The technology of ethanol production from biomass feedstock consists of several steps and varies depending on the type of raw materials used. It becomes more sophisticated as the raw materials turn from sugars to starches and cellulosic materials. Unlike starch, the specific structure of cellulose favors the ordering of the polymer chains into tightly packed, highly crystalline structures that are water-insoluble and resistant to polymerization. For the production of ethanol from the lignocellulosic feedstock, four major unit operations are required: pretreatment, hydrolysis, fermentation, and separation purification (Solomon et al., 2007; Taherzadeh and Karimi, 2007. Mosier et al, 2005).

2.8.1.1. Pretreatment

Pretreatment of biomass is technically challenging and forms a large part of the process cost and therefore will need to be optimized before commercialization. Due to the different types of carbohydrates contained in biomass, a package of enzymes/microbes will be required for hydrolysis and fermentation; this package is a significant process cost and requires optimization (Cellulosic ethanol, 2010). The effect of pretreatment of lignocellulosic materials has been recognized for a long time. The purpose of the pretreatment is to remove lignin, reduce cellulose crystalline and increase the porosity of the materials. Pretreatment must meet the following requirements: Improve the formation of sugars or the ability to subsequently form sugars by acidic or enzymatic hydrolysis; avoid the degradation or loss of carbohydrate; avoid the formation of byproducts inhibitory to the subsequent hydrolysis and fermentation processes. Physical, chemical, Physico-chemical, and biological processes have been used for pretreatment of lignocellulosic materials (Nirbhay Gupta, 2008).

Physical Pretreatment

Mechanical Commination: teff husk materials can be comminuted by a combination of chipping, grinding and milling to reduce cellulose crystalline. The size of the materials is usually 10–30 mm after chipping and 0.2–2 mm after milling or grinding. Vibratory ball milling is more effective in breaking down the cellulose of spruce and aspen chips and improving the digestibility of the biomass than ordinary crystallinity ball milling. The power requirement of the mechanical commuination of agricultural materials depends on the final particle size and the teff husk characteristics (Nirbhay Gupta, 2008).

Ozonolysis: Ozone can be used to degrade lignin and hemicellulose in many lignocellulosic materials such as wheat straw, bagasse, green hay, peanut, pine, cotton straw, and poplar sawdust. The degradation was essentially limited to lignin and hemicellulose was slightly attacked, but cellulose was hardly affected. Ozonolysis pretreatment has the following advantages: it effectively removes lignin; it does not produce toxic residues for the downstream processes, and the reactions are carried out at room temperature and pressure. However, a large amount of ozone is required, making the process expensive.

Pyrolysis: Pyrolysis has also been used for the pretreatment of lignocellulosic materials. When the materials are treated at temperatures greater than 300°C, cellulose rapidly decomposes to produce gaseous products and residual char. The decomposition is much slower and less volatile products are formed at lower temperatures. Mild acid hydrolysis (1 N H_2SO_4, 97 °C, 2.5 h) of 20 the residues from pyrolysis pretreatment has resulted in 80–85% conversion of cellulose to reducing sugars with more than 50% glucose. The process can be enhanced with the presence of oxygen. When zinc chloride or sodium carbonate is added as a catalyst, the decomposition of pure cellulose can occur at a lower temperature (Nirbhay Gupta, 2008).

Chemical Pretreatment

Acid-catalyzed: Concentrated acids such as H_2SO_4 and HCl have been used to treat lignocellulosic materials. Although they are powerful agents for cellulose hydrolysis, concentrated acids are toxic, corrosive and hazardous and require reactors that are resistant to corrosion. Also, the concentrated acid must be recovered after hydrolysis to make the process economically feasible. Dilute acid has been successfully developed for the pretreatment of lignocellulosic materials. The dilute sulfuric acid pretreatment can achieve high reaction rates and significantly improve cellulose hydrolysis. At moderate temperature, direct scarification suffered from low yields because of sugar decomposition. The high temperature in dilute acid treatment is favorable for cellulose hydrolysis. There are primarily two types of dilute acid pretreatment processes: high temperature (greater than 160°C), continuous-flow process for low solids loading (5–10% (weight of substrate/weight of reaction mixture)), and low temperature (less than 160 °C), batch process for high solids loading (10–40%). Although dilute acid pretreatment can significantly improve the cellulose hydrolysis, its cost is usually higher than some Physico-chemical pretreatment processes. Neutralization of pH is necessary for the downstream acidic or enzymatic hydrolysis or fermentation processes (Alemayehu, 2015).

Alkaline Pretreatment: Some bases can also be used for pretreatment of lignocellulose materials and the effect of alkaline pretreatment depends on the lignin content of the materials. The mechanism of alkaline hydrolysis is believed to be the saponification of intermolecular ester bonds cross-linking xylan hemicelluloses and other components, for example, lignin and other hemicelluloses. The porosity of the lignocellulosic materials increases with the removal of the crosslinks. Dilute NaOH treatment of lignocellulosic materials caused swelling, leading to an increase in internal surface area, a decrease in the degree of polymerization, a decrease in crystallinity, separation of structural linkages between lignin and carbohydrates, and disruption of the lignin structure. The digestibility of NaOH-treated hardwood increased from 14% to 55% with the decrease of lignin content from 24–55% to 20%. However, one of dilute NaOH pretreatment was observed for softwoods with lignin content greater than 26%. Dilute NaOH pretreatment was also effective for the hydrolysis of straws with a relatively low lignin content of 10–18% used the combination of irradiation and 2% NaOH for pretreatment of corn stalk, cassava bark, and peanut husk. Ammonia was also used for the pretreatment to remove lignin and ammonia recycled percolation process for the pretreatment of corn cobs/ Stover mixture and switch grass. The efficiency of delignification was 60–80% for corn cobs and 65–85% for Switch grass (Nirbhay Gupta, 2008).

Steam Explosion (Auto hydrolysis): Steam explosion is the most commonly used method for the pretreatment of lignocellulosic materials. In this method, chipped biomass is treated with high-pressure saturated steam and then pressure is swiftly reduced, which makes the materials undergo explosive decompression. Steam explosion is typically initiated at a temperature of 90 - 160 ºC for several minutes to a few hours the material is exposed to atmospheric pressure. The process causes hemicellulose degradation and lignin transformation due to high temperature, thus increasing the potential of cellulose hydrolysis and steam treatment with dilute acid of 0.5 to 1%, the temperature of 90 to 140^{o}C and residence time of 10 to 40 minutes gives the highest yield of ethanol (Solomon, 2007). The advantages of steam explosion pretreatment include the low energy requirement compared to mechanical commination and no recycling or environmental costs. The environmental mechanical methods require 70 % more energy than a steam explosion to achieve the same size reduction.

Steam explosion is recognized as one of the most cost-effective pretreatment processes for hardwoods and agricultural residues, but it is less effective for softwoods. Limitations of the steam explosion include the destruction of a portion xylan fraction, incomplete disruption of the lignin-carbohydrate matrix and generation of compounds that may be inhibitory to microorganisms used in downstream processes. Because of the formation of degradation products that are inhibitory to microbial growth, enzyme hydrolysis and fermentation, pretreated biomass needs to be washed by water to remove the inhibitory materials along with water soluble hemicellulose (McMillan, 1994).

2.8.1.2. Hydrolysis

Hydrolysis is a process where carbohydrate polymers are converted to simple fermentable sugars. In the hydrolysis reaction, the complex chains of sugars in lignocellulose are broken, releasing simple sugars. The complex hemicellulose sugars are converted to a mix of soluble five-carbon sugars, xylose and arabinose, and soluble six-carbon sugars, mannose, and galactose. The rest of the hemicelluloses are degraded to weak acids, furan derivate, and phenolic. These compounds, however, are potential fermentation inhibitors (Cellulosic Ethanol, 2010). By the action of acids and/or enzymes, the glucose yields of cellulose hydrolysis often exceed 90%, but hydrolysis without preceding pretreatment yields typically less than 20% only.

The pretreated feedstock can be hydrolyzed by two methods (Cellulosic Ethanol, 2010).

$$\text{Cellulose} \xrightarrow{\textbf{Hydrolysis}} \text{Glucose} \quad (2.1)$$

$$\text{Hemicelluloses} \xrightarrow{\textbf{Hydrolysis}} \text{Pentose and Hexoses} \quad (2.2)$$

Acid hydrolysis: Acids have been used to catalyze (speed up) the hydrolysis of starch in “starch cookers” operating at temperatures of 50 to 150°C, a process referred to as acid hydrolysis. Acid pretreatment for ethanol production was developed in Germany in the 19th century. In the United States, the U.S. Forest Service, Forest Products Laboratory (FPL) conducted extensive research using acid pretreatment for ethanol production from wood (Zhu et al., 2008). There are two basic types of acid processes: dilute acid and concentrated acid, each with variations. Dilute acid processes are conducted under high temperature and pressure and have reaction times in the range of seconds or minutes while concentrated acid process conducted under low temperatures and pressures employed allows the use of relatively low-cost materials such as fiberglass tanks and piping (Zhu et al., 2008).26

Dilute Acid Processes: Most dilute acid processes are limited to a sugar recovery efficiency of around 60 to 75%. The reason for this is that at least two reactions are part of this process. The first reaction converts the cellulosic materials to sugar and the second reaction converts the sugars to other chemicals. Unfortunately, the conditions that cause the first reaction to occur also are the right conditions for the second to occur. Thus, once the cellulosic molecules are broken apart, the reaction proceeds rapidly to break down the sugars into other products most notably furfural, a chemical used in the plastics industry. Not only does sugar degradation reduce sugar yield, but the furfural and other degradation products can be poisonous to the fermentation microorganisms. (Mohammad, 2008) the optimum results of ethanol yield from citrus peel waste were obtained at a temperature of 116 ^{o}C, 1 % sulfuric acid concentration, and 12.5 min retention time (Cellulosic Ethanol, 2010). The biggest advantage of dilute acid processes is their fast rate of reaction, which facilitates continuous processing. The biggest disadvantage is its low sugar yield. For rapid continuous processes, to allow adequate acid penetration, feedstock must also be reduced in size so that the maximum particle dimension is in the range of a few millimeters. Since 5-carbon sugars degrade more rapidly than 6-carbon sugars, one way to decrease sugar degradation is to have a two-stage process. The first stage is conducted under mild process conditions to recover the 5-carbon sugars while the second stage is conducted under harsher conditions to recover the 6-carbon sugars. Unfortunately, sugar degradation is still a problem and yields are limited (Cellulosic Ethanol, 2010).

Concentrated Acid Process: Concentrated acid process uses relatively mild temperatures and the only pressures involved are usually only those created by pumping materials from vessel to vessel. One concentrated acid process was first developed by USDA and further refined by Purdue University and the Tennessee Valley Authority. In the TVA concentrated acid process, corn Stover is mixed with dilute (10%) sulfuric acid, and heated to 100ºC for 2 to 6 hours in the first (or hemicellulose) hydrolysis reactor. The low temperatures and pressures minimize the degradation of sugars. To recover the sugars, the hydrolyzed material in the first reactor is soaked in water and drained several times. The solid residue from the first stage is then dewatered and soaked in a 30% to 40% concentration of sulfuric acid for 1 to 4 hr as a pre cellulose hydrolysis step (Cellulosic Ethanol, 2010).

This material is then dewatered and dried with the effect that the acid concentration in the material is increased to about 70%. After reacting in another vessel for 1 to 4 hr at 100ºC, the reactor contents are filtered to remove solids and recover the sugar and acid. The sugar-acid solution from the second stage is recycled to the first stage to provide the acid for the first stage hydrolysis. The sugars from the second stage hydrolysis are thus recovered in the liquid from the first stage hydrolysis (Cellulosic Ethanol, 2010). The primary advantage of the concentration process is the high sugar recovery efficiency, which can be on the order of over 90% of both hemicellulose and cellulose sugars. The low temperatures and pressures employed allow the use of relatively low-cost materials such as fiberglass tanks and piping. 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 (Cellulosic Ethanol, 2010).

Enzyme hydrolysis

Enzymatic hydrolysis is a method in which celluloses are utilized for the hydrolysis. This is a quite new approach compared to concentrated-acid and dilute-acid hydrolysis. Cellulolytic enzymes were discovered during World War II when American scientists found the agent that was responsible for army clothing deterioration in the jungles of the South Pacific. The organism responsible for producing the cellulolytic enzymes was Trichodermareesei, which today is used in the enzyme industry for producing a wide range of commercial enzymes (Sheehan and Himmel, 1999). The celluloses involved in the hydrolysis of lignocellulose include endoglucanases, which attack low-crystallinity regions of the cellulose fiber and generate free chain-ends, and exoglucanases, which remove cellobiose from the free chain ends. Then, glucosidase hydrolyzes cellobiose to glucose (Sun and Cheng, 2002). However, pretreatment of the lignocellulose before the enzymatic hydrolysis is necessary to achieve feasible reaction rates. The pretreatment aims to make the cellulose more accessible to enzymatic attack due to the weakening of the protecting lignin and hemicellulose matrix or due to alteration of the pores in the material. There is a wide range of different pretreatment methods. Steam explosion and dilute-acid pretreatment are among the most common (Sun and Cheng, 2002).

The advantages of enzymatic hydrolysis are high yields, due to the highly specific cellulose conversion, and that the reaction is performed at moderate temperatures. Furthermore, byproduct formation is low. The disadvantages are the slow reaction rate of the enzymes and the high enzyme cost (Lynd et al., 2005). Ethanol production by enzymatic hydrolysis can be performed in a Separate Hydrolysis and Fermentation (SHF) mode or a Simultaneous Scarification and Fermentation (SSF) mode. In the SHF process, hydrolysis is performed separately from fermentation, which means that the optimal temperatures for both the enzymatic hydrolysis and fermentation can be applied. A drawback with SHF is that the generated cellobiose functions as cellulases inhibitors (Mandels and Reese, 1963). It has also been proved that J- glycosidase can be inhibited by glucose (Holtzapple et al., 1990). Another drawback is that SHF is a two-step process. To reduce the risk for enzyme inhibition and reduce the number of process steps, SSF can be used. In SSF, hydrolysis and fermentation occur at the same time, which means that the glucose that is generated is immediately consumed by the fermenting microorganism and inhibition of J-glycosidase is therefore prevented. The disadvantage of the SSF process is that the optimal temperatures for the cellulases and the fermenting microorganism are not the same so the selected temperature is a compromise, which means that neither hydrolysis nor fermentation will be performed under optimal conditions (Lynd et al., 2005). Recently, efforts have been made to combine cellulose production, hydrolysis, and fermentation in one single step. This concept is called Consolidated Bio-Processing (CBP) and the aim is to create a microorganism that can perform these three steps simultaneously (Lynd et al., 2005). There are two different strategies to create a CBP microorganism: A naturally occurring cellulolytic microorganism can be modified by genetic engineering to gain important properties, such as the ability to give high ethanol yields, or a non-cellulolytic microorganism that gives high ethanol yields can be altered by genetic engineering to express heterologous celluloses (Lynd et al., 2005).

Today, most research efforts are focused on enzymatic hydrolysis because of the high development potential. The dilute-acid and concentrated-acid hydrolysis are relatively mature techniques for which no major improvements are likely to happen. Nevertheless, the enzyme cost 29 is still high for the enzymatic process. The cost of an enzyme in the SSF and SHF processes has been calculated to be 10-20% of the total ethanol production cost (Wingren et al., 2005).

2.8.1.3. 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). Under anaerobic condition, Saccharomyces Cerevisiae produces ethanol from hexoses as the overall shows below in equation (2.3) and (2.4). The drawback of Saccharomyces cerevisiae is not produce ethanol from xylose but Pichiastipitis yeast produces 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).

$$\mathrm{C6H12O6} \xrightarrow{\qquad\qquad} \mathrm{2C2H5OH + 2CO2} \qquad (2.3)$$

$$\mathrm{3C5H10O5} \xrightarrow{\qquad\qquad} \mathrm{5C2\ H5OH + 5CO2} \qquad (2.4)$$

In theory, the conversion of glucose or xylose to ethanol is 0.51 g EtOH/g glucose. However, the fermenting efficiency of the yeast is generally assumed to be 90% and therefore result in a maximum conversion of 0.46 g EtOH/g glucose (Öhgren et al., 2007). When the glucose yield is high, the ability of Cerevisiae has to produce ethanol also under aerobic conditions (Brand berg, 2005). One drawback is that it cannot ferment pentose, which are an interest when using lignocellulosic biomass. Studies have therefore been performed to genetically modify S. Cerevisiae to become both a pentose and glucose-fermenting yeast. Other microorganisms can ferment pentose and another way to ferment lignocellulosic material is therefore to use different yeasts and to separate the two processes; glucose fermentation and pentose fermentation.

The efficiency of the 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

S.cerevisiae are normally pH 5.0 and a temperature of maximum of 37^{0}C (Alfani et al., 2000). The performance of the process is affected by different inhibitors generated from the upstream process steps. Hydrolyzes contain, together with fermentable sugars, inhibitors which restrict the fermenting microorganisms and thus, decrease the ethanol yield. Recirculation of the process water increases these compounds further (Olsson and Hahn-Hägerdal, 1996). The mixture of inhibitors inhibits the growth and ethanol production of the microorganism. Different bacteria have varying tolerance against these inhibitors, thus S. cerevisiae has proven to be the most robust one

(Almeidaet al., 2007). Also, ethanol, the product itself, has an inhibiting effect on the fermenting microorganism, thus limits the conversion of glucose to ethanol (Alemayehu, 2015)

2.8.1.4. 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 the 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 Bioethanol is initially obtained in a mixture with water. The ethanol is then extracted from this solution by fractional distillation. Although the boiling point of ethanol, 78.3^0C, is significantly lower than the boiling point of water, 100^0C, these materials cannot be separated 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 78.15^0C. In 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 the same composition as the liquid; towards distillation, then, 95% alcohol behaves exactly like a pure compound (Amhare, 2016). The co-product (DDS) is also subsequently dried using the absorption of water containing in it. The solid residue separated from the stillage is centrifuged to separate syrup from a protein concentrate, which is a high quality of animal feed (Kozyukov and Lapidus, 2008)

2.8.1.5. 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, the ethanol phase, and the gasoline phase. It is easy to imagine that this inhomogeneous 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 9596% 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 azeotropic distillation.

Molecular sieves: There is a lower bound on the fraction of ethanol entering the molecular sieve (0.8). Adsorption takes place at 95 °C. The heat exchanger heats the inlet stream from the mixer up to 95 °C. The molecular sieve is a bed of zeolite that operates in semi-continuous mode. The bed is saturated with water after some 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 (or dehydrated) using air under vacuum. The heat exchanger heats the 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 the heat exchanger and this stream leaves this exchanger saturated with water at 25 °C.

Chapter Three

3. Material and methodology

3.1. The materials used in the study

3.1.1. Equipment

- Plastic bags: - to collect and transport samples to the laboratory.
- Grinder: - to grind the dried sample.
- Mass balances: - to weigh samples and yeast.
- Sieves-to filter based on their size.
- Thermometer: - to measure the temperature of the sample under experiment.
- Vessels: - to hold samples.
- Conical flask: - to hold the sample
- Centrifuge: for separation of liquid from solid
- Cylinders of different volumes: - for volume measurement.
- Fermenter: -for fermentation process
- Fractional Distillation: to separate bioethanol from water
- Molecular sieve:- for the dehydration process
- Hydrometer: for measuring the specific gravity of sample feed and leave from the fermenter

3.1.2 Chemicals

- Sulfuric Acid: - use as pretreatment and hydrolysis of teff husk
- Yeast: for the fermentation process
- Distilled water: for hydrolysis process and preparation of sample
- NaOH:- neutralization(for adjust pH)
- Iodine: to test the presence of carbohydrate
- Benedict solution: to test the conversion of polysaccharide to monosaccharide (glucose)

For media preparation

- Sugar (Dextrose)
- Yeast extract
- Urea
- Makeup water

- Mg SO_4.7 H2O

3.2 Procedure of Bioethanol Production

This thesis project is done on the production of bioethanol from teff husk, in Wolkite university college of engineering and Technology, department of chemical engineering. The following methods are the process, which is followed to obtain the target products. This section describes the methodologies and approaches of how experiments are done in this thesis project; it included all steps and procedures of the experiments.

The followings are basic steps for the production of bioethanol:-

- Sample collection
- Grinding process
- Size separation
- Analysis of samples
- Acid hydrolysis to break down the polysaccharide molecules of teff husk to simple sugars.
- Media preparation for yeast
- Fermentation process
- Distillation to produce Bioethanol
- Dehydration

3.2.1 Sample collection and pretreatment

Procedure:

- The sample is collected from the farm of rural area of Wolkite.
- After that, this dry sample is ground into fine particles (i.e. ≤1mm).
- Then this article is separated based on their size by using a sieve, which has a mesh size of 1mm. The maximum particle sizes of the ground mix sample will 1mm.
- The sample of larger particle size than 1mm is ground again until all particle sizes is become (≤1mm).

3.2.2 Raw material characterization

3.2.2.1 Moisture content

Procedure:

- First, three different empty Petridis is measured by using digital mass balance
- Then,10g of the sample is measured on this balance by putting on separate Petridis
- After that, all samples are taken to the oven, and dried for three hours at 105^{o}c
- Finally, these samples are taken out and measure.

3.2.2.2 Ash content

Procedure:

- First, three different empty crucide is measured by digital mass balance
- Then,10g of the sample is measured on this balance by putting on separate crucide
- Next, all samples are taken to the stove to burned some organic compounds from the powder for 10 minutes at 300^{o}c
- After that, they are taken to the furnace and burn at 550^{o}c for 5hours. • Finally, these samples are taken out and measure

Figure 3.1.Image of sample burned ash

3.2.2.3 Carbohydrate content

- The teff husk is collected from the source is characterized as the following by using the iodine test.
- 2g of the Teff husk powder is mixed with 4ml of distilled water;
- Then, it will soak until it is mixed well
- After that, three droplets of iodine solution is added to the sample;
- Finally, it is observing the color change make.

Figure 3.2 frist image befor added and after added iodine solution

3.2.2.4 Sample preparation

Procedure:

- 100g of the ground sample is added into 1000 ml conical flasks
- After that, 1000ml of distilled water is add to it
- Then, conical flasks is caped.

3.2.3 Hydrolysis

The lower and higher limit value of parameters for dilute acid hydrolysis are mentioned as the below.

The table below the lower and higher limit value of parameters for dilute acid hydrolysis

Factors	Minimum	Medium	Maximum
Temperature(^{0}c)	100	116	132
Acid conc. (%)	0.5	2.25	4
Time (min)	5	12.5	25

The experiment is performed to determine the effect of acid concentration on hydrolysis at Constant temperature.

Table blow experimental design to determine the effect of acid concentration on hydrolysis at a constant temperature

R.NO	Acid concn. (%)	Temperature (^{0}c)	Time,(min)
1	0.5	100	25
2	2.25	100	25
3	4	100	25

Figure 3.3 image of sample hydrolyzation

Procedure for a run one

- 0.5% diluted sulfuric acid is added to the sample from pretreatment steps and soak for 24hr to mix it well.
- Then the sample is hydrolyzed in the reactor around 100^{0}c for 25minute.
- Benedict solution is prepared in another beaker
- The conversion of polysaccharide molecule into monosaccharide is tasted by benedicts solution at a different time (min)

Procedure for run two

- 2.25%diluted sulfuric acid is added to the sample from pretreatment steps and soak for 24hr to mix it well.
- Then the sample is hydrolyzed in the reactor around 100 ^{0} c for 25minute.

- The conversion of polysaccharide molecule into monosaccharide is tested by benedict solution at a different times (min).

Procedure for run three

- 4% diluted sulfuric acid is added to the sample from pretreatment steps and soak for 24hr to mix it well.
- Then the sample is hydrolyzed in the reactor around 100 ^{o}c for 25minute.
- The conversion of polysaccharide molecule into monosaccharide is tested by Benedict solution at a different time (min).

3.2.4 Adjustment of PH

Procedure:

- The soluble part from treatment and hydrolyzed sample is mixed together and shack
- Then, the PH of the sample is measured and it reads.
- Next, 10M NaOH is added in drop wise until it reaches around 6.5 to 7
- Finally, the pH of the sample is adjusted to 6.5 to 7.0.

3.2.5. Centrifuge Separation

Procedure:

- The mixture of the sample is feed to a tube of centrifuge
- Then, the power is supplied to it after that the sample is separated according to their phase
- Finally, the liquid part is sent to the fermenter, whereas the residue part is taken to another flask to produce Dried Solid (DS)

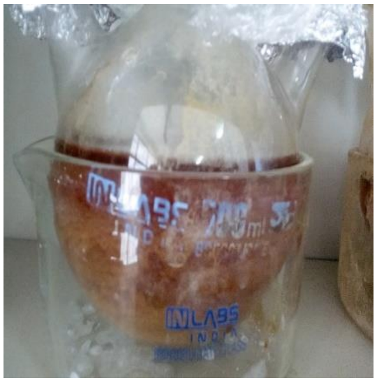


Figure 3.4 frist image solid part and seconde image liquid part

3.2.6. Media preparation

- ✓ To prepared 100ml media,
- Sugar (Dextrose)=10g
- Yeast extract =0.2gm. • Urea=1.0gm
- Makeup water=100ml
- $MgSO4.7H2O$=1.0g
- ✓ Procedures in Media Preparation
- To the prepared media, 0.5gm of yeast, Saccharomycescrevia is added in a 250 ml volumetric flask.
- Then, the flasks is properly covered, and soaked for 24hr

3.2.7 Fermentation

The lower and higher limit value of major parameters for the fermentation process is mentioned below.

Table lower and higher limit value of parameters for fermentation for Bioethanol production

Factor	Minimum	medium	maximum
Temperature (^{o}c)	30	35	40
PH	5.5	6.25	7
Time (days)	3	5	7

In this study, the effect of PH on fermentation done by holding other parameters constant Table experimental design to determine the effect of pH on the fermentation process

R. NO.	PH	Temperature (^{0}c)	Time (Day)
1	5.5	30	3
2	6.25	30	3
3	7	30	3

Procedure for a run one:

- In the beginning, fermenter is sterilized by heat
- Then, the hydrolyzed sample with pH 5.5 is added to the fermenter
- Next to this, The yeast (10% with the proportion of 1:10 that is yeast and sample respectively) is added to it
- Then, the temperature and duration time is set to 30°C, and 72 hrs respectively
- Finally, after around 72 hours of fermentation, the samples are taken out and then passé to distillation

Procedure for run two:

- In the beginning, fermenter is sterilized by heat
- Then, the hydrolyzed sample with pH 6.25 is added to the fermenter
- Next to this, The yeast(10% (with the proportion of 1:10 that is yeast and sample respectively) is added to it
- Then, the temperature and duration time is set to 30°C, and 72 hrs respectively
- Finally, after around 72 hours of fermentation, the samples are taken out and then passé to distillation.

Procedure for run three:

- In the beginning, fermenter is sterilized by heat
- Then, the hydrolyzed sample with pH 7 is added to the fermenter;
- Next to this, The yeast(10% (with the proportion of 1:10 that is yeast and sample respectively) is added to it
- Then, the temperature and duration time is set to 30°C, and 72 hrs respectively;
- Finally, after around 72 hours of fermentation, the samples is taken out and then passé to distillation

3.2.8 Distillation

Procedure:

- The liquid solution which is the mixture of bioethanol and water is fed to the round flask (sample holder) of distillation column
- Then, the thermometer is inserted to the upper part of the adapter, and the temperature of the process is set to 85^0c
- Finally, Bioethanol is separated from water through the top column and condensed by the condenser, and collected in its collector.

Chapter 4

4. Sample analysis method

4.1 Analysis of Experimental Result statistically

As mentioned above, production of bioethanol from teff husk pass through for major process like pretreatment, hydrolyzation, fermentation, and distillation. For each process the experimental done and the result obtained is mentioned and discussed in this chapter.

4.1.1 Sample characterization

The raw material collected (teff husk) from the farm was characterized by the following.

- **Moisture content**

The moisture content of teff husk powder is determined after it is dried in the oven as the following.10g of sample was put on three different Petridis and placed in oven for 3 hrs. At 105^0 c after that the mass of the sample is measured before and after dried

Then, before dried mass of sample A=10g, B =10g, C=10 g

Again, after dried mass of sample A=9.2g B=9.5g C=9.4g

The moisture content of sample is determined by the following formula Moisture content (%) = (w1-w2) w1*100 Where, w1=initial mass of the sample before dried

w2=mass of the sample after dried Therefore, Moisture content of:-

A (%) = (10g-9.2g)/10g*100 =0.08

B (%) = (10g-9.5g)/10g*100 =0.05

C (%) = (10g-9.4g)/10g*100 =0.06.

Then, the moisture content of teff husk powder is the average of these three samples

Moisture (%) = (MA+MB+MC)/3

Where:

MA is moisture content (%) of sample A

MB is moisture content (%) of sample B

MC is moisture content (%) of sample C

Moisture (%) = (0.08+0.05+0.06)/3 = 0.66

Hence, the moisture content of teff husk powder is 0.66%

- **Ash content**

The Ash content of teff husk powder is determined as the following 10g of sample was put on three different crucible grand then it is burned on stove at 300oc for 10 minute, and subsequently in the furnace at 550^0 c for 5 hrs. After that the mass of the sample is measured before and after dried. Then, before burned mass of sample A= 10g =3, B=10g, C=10g.

Again, after burned mass of sample 1A=6.67g 1B=6.57g 1C=6.78g.

The Ash content of the sample dry basis is determined by the following formula,

Ash content (%) = (m1)/m2*100

Where: m1=initial mass of the sample before burned

m2= mass of the sample after burned.

Therefore: Ash content of A (%) = 6.67/10g*100 = 66.7

Ash content of B (%) = 6.57/10g*100 =65.7

Ash content of C (%) =6.78/10g*100 =67.8.

Then, the Ash content of teff husk powder is the average of these three samples

Ash content (%) = (A+B+C)/3

Where:

A is Ash content (%) of sample A

B is Ash content (%) of sample B

C is Ash content (%) of sample C

Ash content (%) = (66.7+65.7+67.8)/3=20.74/3

=68.8.

Hence, the Ash content of teff husk powder is 0.68%

- **Carbohydrate content**

This is the most important characterization of the raw material collected. Because, being having carbohydrate is one of the most important criteria to produce bioethanol from the selected material. Due to the fact that most of husk is considered as the lignocellulose biomass which contains cellulose, hemicellulose, and lignin. It is necessary to determine whether teff husk contains polysaccharide carbohydrate molecules or not. So that the sample is characterized by using iodine test. In this study the presence of carbohydrate is tested by its color change. When iodine solution is added to the sample, the color of the sample is changed from brown to blue black color. Hence we analyzed that there is carbohydrate molecule in the teff husk. Carbohydrate is mainly classified into three major categories, such as polysaccharide (cellulose, hemicellulose, and starch), disaccharide (sucrose, maltose,), and monosaccharide (glucose, fructose, and galactose). Among these categories since teff husk is lignocellulose biomass it is classified under polysaccharide molecules. So that, it has the substantial potential for production of bioethanol by passing through different steps.

4.2 Hydrolysis

The followings are experimental done with different concentration of dilute acid hydrolysis to determine its effect on rate of hydrolysis process.

No.	Acid con (%)	Tem (^{0} c)	T (min)
1.	0.5	100	30
2.	2.25	100	30
3.	4	100	30

As mentioned above in this study the effect of dilute acid concentration (0.5 % to 4%v/v) on rate of hydrolysis is determined at constant temperature (100oc), and time (30min).Three different samples are prepared with different concentration and taken to hydrolysis process. Then, throughout the process each sample was taken and tested by benedict solution at different time with the same interval period (10, 20, 30 min) to test which one is converted to simple sugar (glucose) quickly.

Benedict solution is the solution which used for testing the presence of reducing sugar like glucose, galactose and fructose. In this study, we used this solution to test the conversion of polysaccharide molecule to glucose by observing the color change made when benedict solution is added to the prepared sample. Glucose gives green color when it is reacted with this solution. Hence, the following are the result obtained throughout the process while dilute acid hydrolysis is carried out.

No.	Sample	Acid con (%)	Tem (^{0} C)	Tim (min)	Color change
1	A	0.5	100	10	No change
	B	2.25			No change
	C	4			Little change
2	A	0.5	100	20	Insignificant change
	B	2.25			Little change
	C	4			Changed
3	A	0.5	100	30	Changed
	B	2.25			Changed
	C	4			Changed

Table 4.1 the effect of acid concentration on hydrolysis process at different time

No.	Acid con (%)	Tem (^{0} C)	Rate of conversion
1	0.5	100	Law
2	2.25	100	Medium
3	4	100	High

Table 4.2 the effect of acid concentration on rate of hydrolysis process

Hence, as it is mentioned in the above table the concentration of the acid has great effect on hydrolysis process. At low concentration (0.5%) it takes a time to convert the complex sugar in to simple fermentable sugar, whereas at high concentration (4%) the required glucose is achieved with a short period of time without consuming allot of energy. Therefore, using dilute acid hydrolysis with appropriate concentration is economical.

4.3 Fermentation

In this study the effect of pH on fermentations are done, to select the optimum point which gives economical yield by holding other parameters constant. The followings are different run performed with different samples.

No.	PH	Tem (^{0} c)	Time, Day
1	5.5	30	3
2	6.25	30	3
3	7	30	3

Table 4.3 experimental design to determine the effect of pH on fermentation process

The alcohol content of these samples is calculated The alcohol content can be measured in different method from those methods hydrometer is used this research .Hydrometer is the device used to measure specific gravity (SG) of liquid with respect to water.

Alcohol content (%) = (OG-FG)*(1.05/0.8)*100

Where: OG is original specific gravity,

FG is Final specific gravity

For sample A,

OG =1.07, FG=1.03

Alcohol content (%) = (1.07-1.03)*(1.05/0.8)*100 =5.25%

For sample B,

OG=1.07 FG=1.01

Alcohol content (%) = (1.07-1.01)*(1.05/0.8)*100 = 7.87

For sample C,

OG=1.07 FG=1.02

Alcohol content (%) = (1.07-1.02)*(1.05/.8)*100

=6.563

As we have seen on the above calculation, at constant temperature and time the yield of alcohol from fermenter varies with PH of the sample. In the sample A the solution is acidic than all the other samples, so that they did not form the favorable condition for the growth of yeast which plays an important role in fermentation process. Consequently, the yield of an alcohol obtained from the process is lower than the others. However, in sample B, the PH of the sample is slightly acidic, this is the condition in which yeast prepare to grow, and propagate. Consequently, the yield of Alcohol obtained from the fermenter is higher than the rest. Therefore, PH of sample going to be fermented should be adjusted around slightly acidic (6.00-6.5).

No.	PH	Yield
1	5.5	5.25
2	6.25	7.87
3	7.0	6.563

Table 4.4 the result on the effect of pH on fermentation process

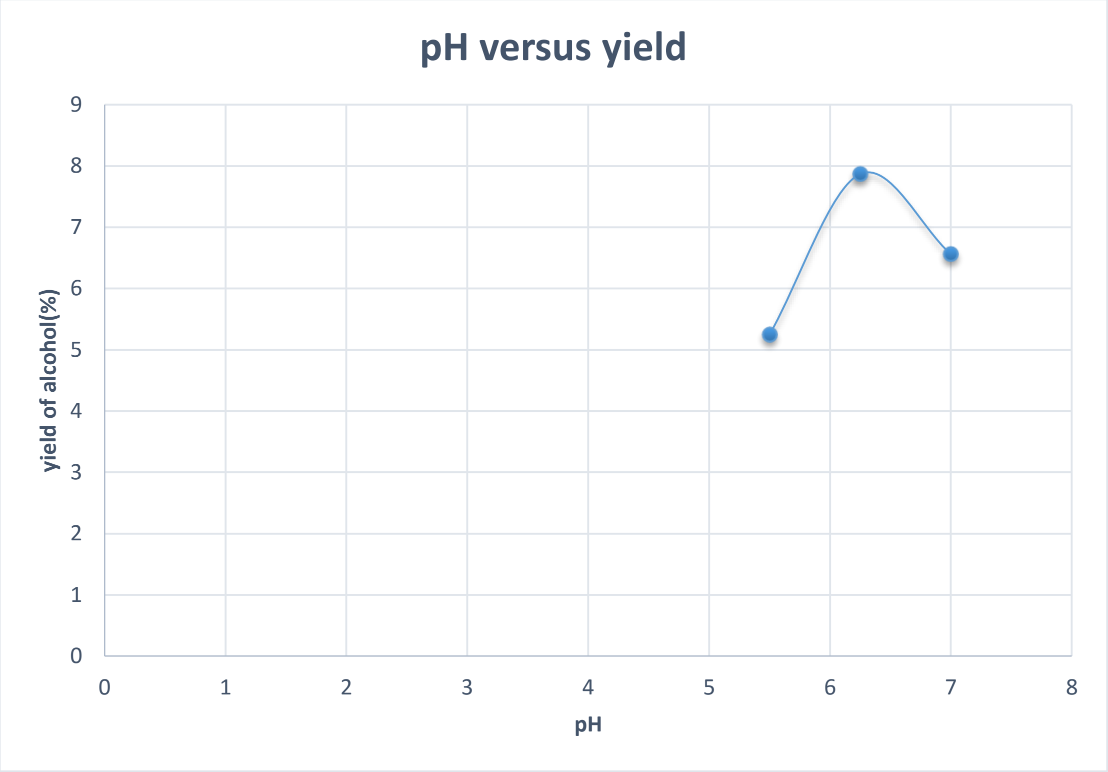


Figure 4.1 P^H Vs Yield graph

4.4 Distillation

The mixture of bioethanol and water feed to the distillation is separated based on their boiling point. The one which has less boiling point (more volatile) i.e. bioethanol is evaporated from the mixture around its boiling point, and then condensed in the condenser. After that the product obtained is collected in the beaker.

4.5 Bio ethanol yield

Yield (%) = m_b/m_{th}

Where, mb is mass of bioethanol produced at the end

Mth is mass of teff husk powder taken for production of bioethanol

$$\text{Yield (\%)} = 100*65\text{ml}*0.790\text{g/ml}100\text{g}$$

$$=51.35\%$$

CHAPTER FIVE

5. MATERIAL AND ENERGY BALANCE

Material and energy balances are very important in an industry .Material balances is the mass balance made the process based on the input and output mass of the material. Mass and energy balance 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. The basic principle for both material and energy balance is simply based on the following equation:

Input + Generation = Output + Consumption +Accumulation

5.1 Material Balance

Material balances calculation is used for the following points

- To stud the plant operation balance and troubleshooting
- To check the performance
- To check instrument elaboration
- To locate source of materials loss
- To design new process and analyze an existing process
- To determine the raw materials required and
- To determine the product produced

✓Assume: operation is steady state operation

✓Basis: 18 hour of operation per day

The Production capacity of the plant is 3.5*106litre/year of bioethanol (99.9%) with plant operation of 260 calendar days per year.

This plant capacity is decided based on the following factors

- Availability of raw materials (teff husk)
- Demand of the product
- Availability of worker (employer, labor)

Product (Anhydrous bioethanol) =yield/Annual operation day= 3.5*106litre/year / (260*18) hr

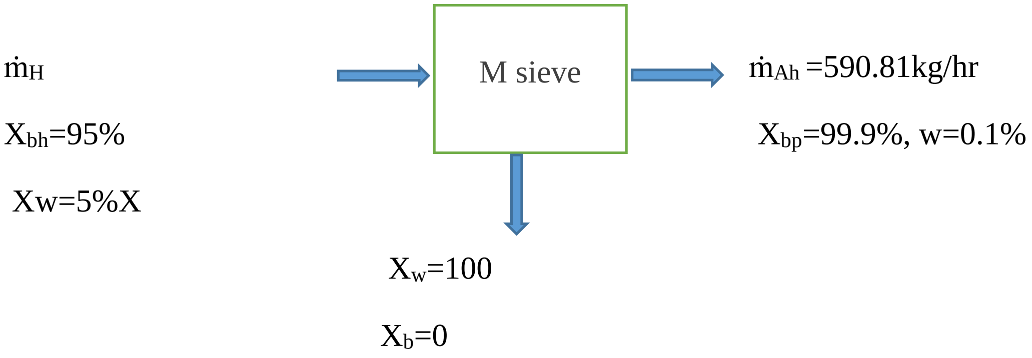
=747.86 liter/hr

Mass of the product =density*volume = 790kg/m3*747.86litre/hr*m3/1000litre

=590.81 kg/hr

Material balance on Molecular sieve

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



Where $\dot{m}_H$ is the hydrous bioethanol $\dot{m}_{Ah}$ is anhydrous bioethanol $\dot{m}w$ is the Mass of water

X_{bh} is the fraction of bioethanol from distillation

X_{bp} is the fraction of bioethanol from molecular sieve

Xw is the fraction of water

Total mass balance

For steady state total mass balance, the input is always equal with output Input=output

$\dot{m}_H = \dot{m}_w+\dot{m}_{Ah}$..(1)

Component mass balance for bioethanol

Input +generation-output-consumption=Accumulation

But, since the process is steady state operation (Accumulation=0), and there is no generation and consumption on bioethanol mass

$$Xbh * \dot{m}H = xbp * \dot{m}Ah$$

$$0.95 * \dot{m}_H = 0.999 * \dot{m}_{Ah}$$

$$0.95 * \dot{m}_H = 0.995 * 590.81 kg/hr$$

$$\dot{m}_H = (590.81\ kg/hr * 0.99)/0.99 =$$

$$\dot{m}_{H} = \frac{590.81 kg / hr * 0.999}{0.95} = 621.28 kg / hr$$

Then, by substituting this value in above equation (1),

We can get Mw $\dot{m}_W = \dot{m}_H - \dot{m}_{Ah} =$ 621.28kg/hr-590.81kg/hr=30.47kg/hr

Hence, the water that is trapped by the molecular sieve is 30.47kg/hr

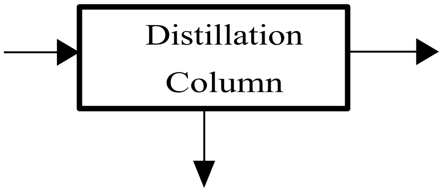
Material balance on distillation column

It is the equipment used for the purification bioethanol from water – ethanol mixture. The mixture taken from fermentation to the distillation with the mixture of 7.58% ethanol and the rest is water, then by using distillation column ethanol is separated from water with the purity of 95%.

$\dot{m}_F$

X_{bf}=7.87%

X_w=92.13%



$\dot{m}_H$=621.28kg/hr

x_{bp}=95%

x_w=5%

$\dot{m}_W$

X_w=100%

X_b=0

Where, $\dot{m}_F$ is the mass of fermented mash

$\dot{m}_H$ is the mass of distilled product

X_{bf} is the fraction of diluted hydrous bioethanol (from fermenter)

X_w is the fraction of water

X_{bp} is the fraction of hydrous bioethanol

Total mass balance Input=output

$\dot{m}_F = \dot{m}_W + \dot{m}_H$...(2)

Component mass balance for bioethanol Input =output, operation, there is no accumulation, generation.

Input=output

$$Xbf*\dot{m}F=Xbp*\dot{m}D$$

$$0.0787*\acute{m}_F=0.95*621.28kg/hr=590.22kg/hr$$

$$\dot{m}_F= 590.22kg/hr/0.0787=$$

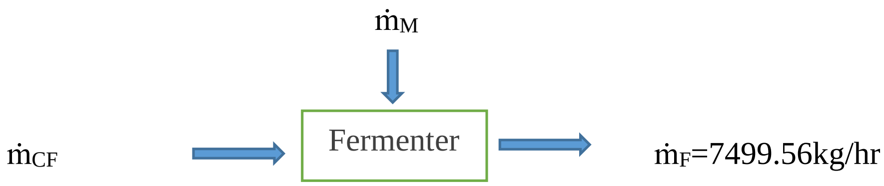
$$7,499.56 \text{ kg/hr}$$

Therefore, the amount of water separated from bioethanol in this distillation column can be calculated by substituting this $\acute{m}_F$ in equation (2) above

$\dot{m}_W = \dot{m}_F - \dot{m}_H$

$= 7,499.56kg/hr-621.28kg/hr=6,878.28kg/hr$

Material Balance on fermenter



Where, $\dot{m}_{CF}$ is the mass of centrifuge (filter) mash

$\dot{m}_M$ is the mass of media

$\dot{M}_{CO2}$ is the mass of co $_2$ release $\dot{m}_F$ is the mass of fermented mash.

From the reaction of fermentation

$C6H12O6 \longrightarrow 2C2H5OH+2CO2$

180gm/mol 92gm/mol88gm/molfor100%conversion

$$\frac{\dot{m}cF}{180kg/kmol} = \frac{\dot{m}H}{92Kg/kmol}$$

$\dot{m}c_F$ = $\frac{180kg/kmol*621.28kg/hr}{92kg/kmol} = 1,215.55kg/hr$

Then mass of CO_2 produced, is calculated by

$\dot{m}_{GF}$ / 180 = MCO_2/88 $\dot{m}CO2$= $\frac{621.28kg/hr*88kg/k\,mol}{180kg/kmol}$

=303.78kg/hr

Total mass balance on fermenter

Input=output

$\dot{m}_{CF}+\dot{m}_M=\dot{m}_F+\dot{m}_{CO2}$...(3)

However, the amount of yeast added is10% of mass of filter mash

So, $\dot{m}_M$ =0.1*$\dot{m}_{CF}$.. (4)

Then, substitute equation (4) in equation (3)

$\dot{m}CF + 0.1\dot{m}CF=\dot{m}F+\dot{m}CO2$

$1.1\dot{m}_{CF}$=1215.55kg/hr+303.78kg/hr

$\dot{m}_{C\,F}$ = $\frac{1519.28kg/hr}{1.1}$

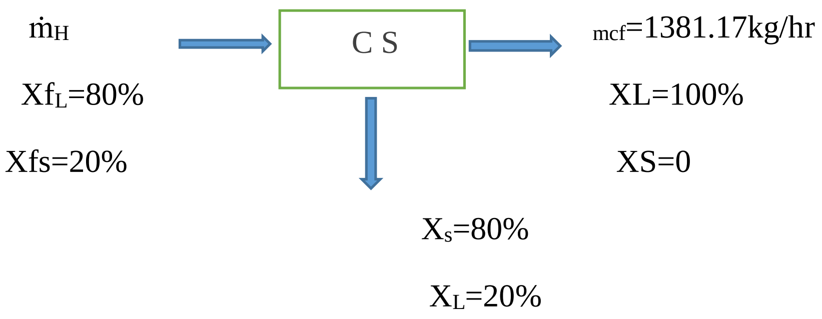
=1381.17kg/hr

And,

$\dot{m}_M$ = 0.1*1381.17kg/hr=138.12kg/hr

Material Balance for Centrifugal separation

Centrifuge is used for separating insoluble solid from liquid. Moisture content of centrifuge solid is20%.



Where:-

$\dot{m}_H$ is mass flow rate of acid treated fluid

$\dot{m}_S$ is mass flow rate of bottom centrifuge solid residue (lignin)

$\dot{m}_{CF}$ is mass flow rate of the centrifuge fluid.

xfL is mass fraction of liquid in hydrolyzed sample xfs is mass fraction of solid in hydrolyzed sample

For the solid component balance $\dot{m}_H*Xf_S=\dot{m}_S*X_S$ $\dot{m}_H*0.2=\dot{m}_S*X_S$

$_{mh=}$ msf*0.8/0.2………………(5)

And, for the liquid component mass balance ṁH*XL=ṁS*XL+ṁCF*XL

$\dot{m}_H*0.8=\dot{m}_S*0.2+1381.7$kg/hr*.. (6)

Substitute equation (5) in (6)

$$\dot{m}S\times0.8\times0.8/02= \dot{m}S*0.2+1381.7\text{kg/hr}$$

$$3.2*\dot{m}_S=0.2*\dot{m}_S+1381.7\text{kg/hr}$$

$$3*\dot{m}_{S=}1381.7\text{kg/hr}$$

$$\dot{m}_S = 1381.7\text{kg/hr}/3$$

$$= 460.57 \text{ kg/hr}$$

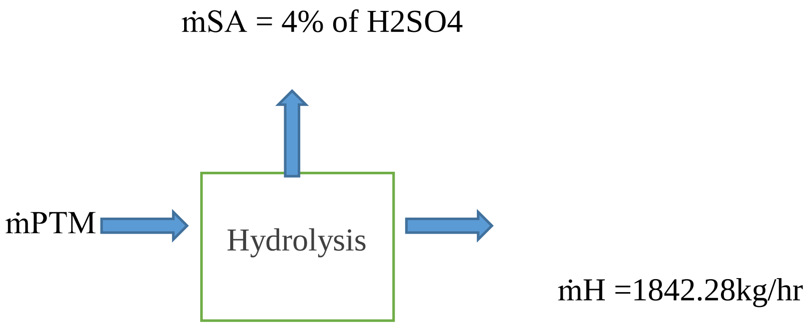
Then, substitute this value in equation (5) above

$$\dot{m}_H=(460.57kg/hr*0.8)/0.2$$

$$=1842.28kg/hr$$

Mass balance on hydrolysis

The pretreated sample is soaked and treated with 4% sulfuric acid to convert cellulose to glucose and serve as catalyst meaning it has no any reaction with starch.



Where, ṁPTM = Mass flow rate of pretreated mixture ṁSA = mass of diluted sulfuric acid Reaction

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

1mole of cellulose = 1 mole of glucose for 100% conversion But not complete conversion and assume that 99% of cellulose converts to glucose.

$=\dot{m}PTM/162kgkmol=\dot{m}\ H/180kgkmol$

$\dot{m}PTM= (162*1842.28)/180 =1658.05\ kg/hr$

Applying total mass balance

Input=output

$$\dot{m}pTM+\dot{m}sA=\dot{m}H$$

$$\dot{m}sA = \dot{m}H-\dot{m}PTM$$

$$=1842.28kg/hr-1658.05kg/hr.$$

$$=184.23\ kg/hr$$

In order to get mass of H2SO4, first we have to change this volume fraction into mass fraction Assume, Basis =100L,

Hence. $v_{H_2SO_4}$=4L, and v_{H_2O}=96L Hydrolysis

Then mass of $_{H_2SO_4}$=density*volume

=1840kg/m3*4L*0.001m3/L=7.36 kg Mass of

$_{H_2O}$=density*volume=1000kg/m3*96L*0.001m3/L=96 kg

Then total mass ($\dot{m}$t) = 7.36kg+96kg=103.36 kg

Therefore, $_{XH_2SO_4}$=$_{\dot{m}H_2SO_4}$/$\dot{m}$

t=7.36kg/103.36 kg = 0.071

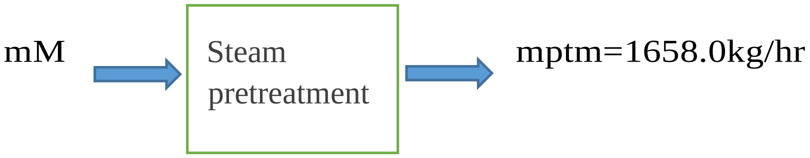
$XH_2O = \dot{m}\ H_2O/\dot{m}t$

=96kg/103.36kg=0.929

Mass of $_{H_2SO_4}$=0.071* $\dot{m}$SA

=0.071*184.23 kg/hr=13.08kg/hr

Mass balance on Autoclave (steam pretreatment)



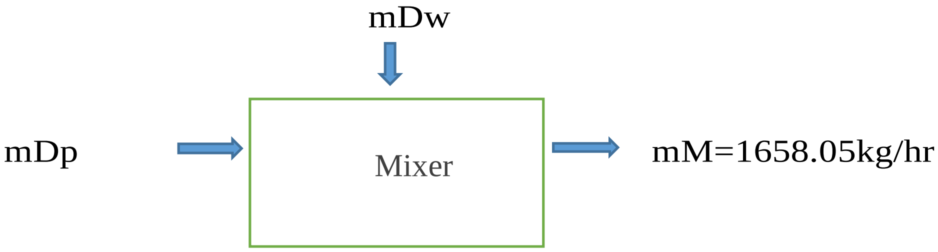
Where,

$\dot{m}$M = is mass flow rate for mixture

Total mass balance Input=output

$\dot{m}$M = $\dot{m}$PTM = 1658.05kg/hr

Material balance on mixer: it is the equipment used to make homogenous suspension of distilled water and dry teff husk powder.



Where: - $\dot{m}$ D P= Mass flow rate of dry teff husk powder

$\dot{m}$D W= Mass flow rate of distilled water Mixer

Steam pretreatment

Total mass balance: Input=output

$$\dot{m}DP + \dot{m}DW = \dot{m}\ M$$

$$\dot{m}DP = \dot{m}M - \dot{m}DW$$

$$=\dot{m}M-10\dot{m}\ DP$$

$$11\dot{m}\ DP=\dot{m}M$$

$\dot{m}DP = \dot{m}_M/11=$

(1658.05kg/hr)/ 11=150.73 kg/hr

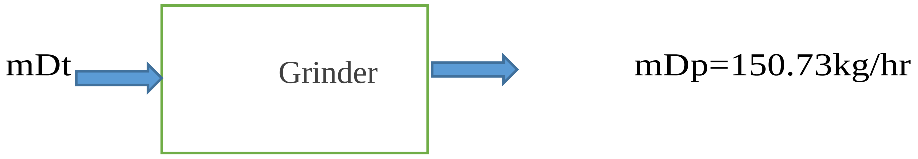
$\dot{m}$ DW=10*$\dot{m}$ D P

=10*150.73 kg/hr

=1507.3 kg/hr

Material balance on grinder

The dried sample is ground in to fine powder, to facilitate the rate of hydrolysis process, and achieving with good yield of glucose product. Once they ground into powder form they are separated by sieve based on their size, those materials which has greater size than 1mm,is ground again and again until they reduced to ≤1mm.Hence,the input and output on grinder are the same.



Where, ṁDt is mass flow rate of dry teff husk

Input=output

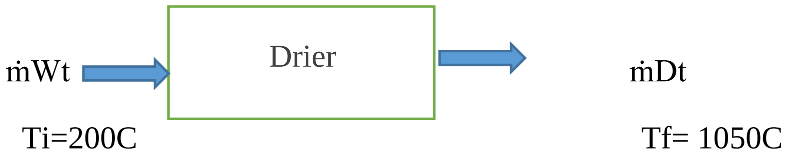
$$\dot{m}Dt=\dot{m}Dp=150.73.kg/hr$$

5.2. Energy Balance

Energy is an important and costly input in the production process of bioethanol. However, conservation of energy is differ from that of mass in that it can be generated ,consumed, and changed from one form to other. In steady state operation mass flow into a process unit must be equal to the flow out from a process. But, the total energy of outlet streams is not equal that of the inlet streams because of energy is generated or consumed in the process due to heat of reaction. In process design energy balances are made to determine the energy requirements of the process. It shows the pattern of energy usage and suggests areas for conservation and savings. Input + Generation = Output + Consumption +Accumulation

Energy balance on dryer

Basis of operation one hour the dryer is used to dry the sample from 200 c to 1050 c.



The energy required for this drying process is calculated as the below,

$$Q=\dot{m}\times cp\times\Delta T$$

Where m =mass of wet teff husk

CP = specific heat of wet teff husk

ΔT =is the temperature difference (Tf- Ti)

The Mass of wet teff husk from material balance is 753.65 kg/hr

$$Cp = 1.6998+0.006113T+0.8499Xw/ (1-Xw)-0.1042Xw/ (1-xw)^2$$

$$Cp = 1.6998+0.006113*293+0.8499*(0.75/ (1-0.75))-0.1042*(0.75)2/ (1- 0.75)^2$$

Cpf=5.10KJ/Kg.k

Average specific heat capacity (cpa) =cpf ×xf +cpw ×xw

=5.1KJ/Kg.k x 0.25 +4.18KJ /Kg.k×0.75

cp =4.41kJ/kg.k

Q =753.65kg/hr ×4.41kg/kg.k × (105 ^{0}C-20 ^{0}C) = 282505.7 KJ/hr

Energy balance on steam pretreatment

T=25 ^{0} C

ṁpM=1658.5kg/hr.

T=121 0C

ṁM

Where, ṁTM = is mass flow rate to pretreated mixture Drier Steam pretreatment

ṁM = ṁ PT= 1658.5kg/hr

The heat required for steam pretreatment is

Q=ṁMCPΔT = (121 -25) ^{0}C* 1658.5kg/hr *5.1kJ/kg = 812001.6kj/hr

Energy balance for hydrolysis

It is the energy used for hydrolysis starch polymer into simple sugar (glucose)

T=25^{0}cT=132^{0}c

$\dot{m}_H$=1842.28kg/hr

$\dot{m}_{PTM}$=1658.05kg/hr.

$\dot{m}_{SA}$ =184.23kg/hr.

CPM= (mSA*CPSA+Mh*CPH)/Msa+Mh

Where:

MSA is of mass of diluted sulfuric acid

CPSA is specific heat capacity of diluted sulfuric acid

CPH is specific capacity of sulfuric acid

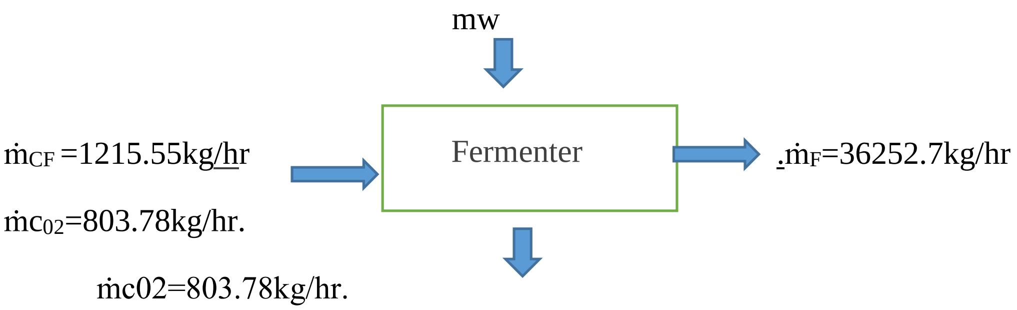
$$CPM = \left(\frac{184.23 \times 5.1 + 1842.28 \times 4.18}{184.23 + 1842.28}\right) {}^{KJ}/_{Kg.k} = 0.84\ {}^{KJ}/_{Kg.k}$$

The heater quire for hydrolysis is

$Q = \dot{m}_H C_P \Delta T$

$= 1842.28 \times 0.84 \times (132-25)^0C = 78849.58 KJ/hr.$

Energy balance for fermenter



Fermentation is an exothermic reaction because heat is generated inside the fermenter and the outlet temperature is 300 C. The energy balance in the fermenter at 00 C reference temperature.

Data;

$C_{p.}$ of mix at $30^0C = 5.16 KJ/Kg.k$ obtained by using the above formula

$C_{p.}$ of CO_2 at $30^0C = 0.846 KJ/Kg.k$

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

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

$Q = \dot{m}_{mix} c_{pmix} \Delta T - \dot{m}_{CO2} C_{P_{CO2}} \Delta T - \dot{m} C_{pf} \Delta T$

$$c_{pf} = c_{pmix} x_{mix} + c_{pc02} x_{c02}$$

$$x_{c02} = \frac{803.78}{36252.7 + 3625.27} = 0.02$$

$$x_{mix} = 1 - 0.02 = 0.98$$

$$c_{pf} = 5.16 \times 0.98 + 0.846 \times 0.02$$

$$c_{pf} = 5.07kj/kg.K$$

$Q=\dot{m}_{mix}c_{pmix}\Delta T - \dot{m}_{CO2}C_{PC02}\Delta T - \dot{m}_{C_F}\Delta T$

$$= \frac{1337.1kg}{hr} \times \frac{5.16kj}{kg.kmol}(30-0)0_c - \frac{803.7kg}{hr} \times \frac{0.02kj}{kg.kmol}(30-0)0_c - \frac{7499.56\text{kg}}{\text{hr}} \times \frac{5.07kj}{kg.kmol}(30-0)0_c$$

$$= \mathbf{-934182.22.8}\ KJ$$

Energy balance on distillation column

From ethanol component balance

Energy balance Basis 250c, 1hr

Specific Heat capacity on top

Cp, distillate =

$$=2.72 *0.95 +(1 -0.95) \times 4.18 =2.79\frac{\text{kJ}}{\text{kg k}}$$

Specific Heat capacity on bottom

Cp water $=4.18\frac{\text{kJ}}{\text{kg}}$

Balance around the main condenser Reflux ratio R=1.2

R= L/D = 1.2

$$\text{L=1.2*D} \quad =1.2 \times \frac{621.28\text{kg}}{\text{hr}} =745.44\frac{\text{kg}}{\text{hr}}$$

V=L+D

= 745.44 kg/hr + 621.28 kg/hr

= 1366.7kg/hr

QB=is determined from a balance over complete system.

Input=Output

QB+HF=QC+HD+HW

Where:

HW=Heat capacity of bottom

HF=Heat capacity of feed

QB=re-boiler heat input

QC=condenser cooling

From vapor liquid equilibrium data Boiling point of 95%alcohol=78.13^{0}C

At steady state operation (Accumulation=o)

Input=output

HF=HD+HL+QC

QC=HF-HD–HL

Assuming complete condensation

Enthalpy of Vapor=Latent +Sensible heat

$HV=\dot{m}_v\lambda_v+\dot{m}_v\lambda_v\Delta T$

$=1366.72*789+1366.72*2.72*(78.13-25)\ ^oc$

=12764836.68 kj/hr

. QB=QC+HD+HW-HF

Heat capacity of feed

$H_F=\dot{m}_F.\ Cp.\Delta T$

= 7499.56*2.79*(35-25)

= 209237.72 KJ/hr

Heat capacity of bottom

$H_w= \dot{m}_w.C_p.\Delta T$

= 6878.28*4.18(100-25)

= 2156340.78 KJ/hr

QB=QC+HD+HW–HF

$$=12764836.68+0+2156340.78-209237.72$$

$$=1271233.74KJ/hr$$

QB is supplied by condensing steam

Latent heat of steam at 274KN/m2, λv=2174KJ/kg

Steam required

$\dot{m}s$ (steam required)= Qb/ λ_v =(1271233.74 kg/hr)/2174Kj/hr

$$= 584.744kg/hr$$

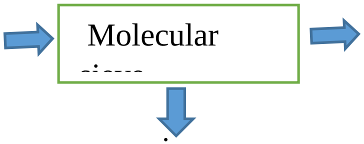
Mass of water that is able to condense is removed by cooling water with temperature rise of 300 ^{0}C

$$QC=\dot{m}_w c_p \Delta T = Hv$$

$$= (12764836.68KJ/hr) / 4.18 KJ/Kg.k$$

$$=101792.9Kg/hr$$

Energy Balance on Molecular sieve



$\dot{m}_H$ = 621.28kg/hr $\dot{m}_{AH}$=590.81kg/hr

X_{bf}=95% x_{bp}=99.5%

Ti=25^o $\dot{m}_W$ TF=95^{o}c

First, Cp is calculated based on the percentage of the input mass of hydrous ethanol

$$Cp=0.95*2.79+0.05*4.18=2.86kJ/kg\ k$$

The temperature entering the molecular sieve is 25 ^{0} C and exit is at temperature of 95 ^{0} C

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

$$=621.28kg/hr*2.86kj/kg.k* (95-25)\ ^oc$$

$$=124380.3kJ/hr.$$

CHAPTER SIX

6. SIZING AND DESIGN OF MAJOR EQUIPMENT

6.1. Sizing

Equipment sizing for this project involves determining the size of the equipment in terms of volume flow rate or surface area (diameter). For most of equipment we have selected carbon steel, because

- It has high corrosion resistances
- It has high strength
- It is no expensive compared to other

Sizing of Grinder (Roller Mill)

Solid to be processed	dried teff husk
Temperature	25^0C(surrounding temperature)
Material of constriction	carbon settle

Then volume of dried teff husk going to be dried is

$=m_{Dt}/\rho_{st}$

However, the volume of of grinder required for the process with 10% safety factor is,

$= (m_{Dt + 0.1}\, m_{D)} / \rho_{st}$

$= (150.73kg/hr + 0.1*150.73kg/hr)/422.5kg/m^3$

$=0.39m^3$

Here, if grinder is filled up to 75%, the required volume will be,

$V=0.39/0.75 =0.52\ m^3$

Sizing of mixer

Slurry to be handled	mixture of water and teff husk powder
Temperature of slurry	25^0C
Materials of construction	carbon steel

Density of slurry (ρ_s) = $\rho_{st}*x_{st}+\rho_w x_w$

=422.5kg/hr*0.1+1000kg/hr*0.9

=942.25 kg/m^3

Volume of slurry to be handled=m/ρ

= (Mm+0.1*Mm)/ ρ

= (1658.05kg/hr+0.1*1658.05kg/hr)/942.25kg/m^3

= 1.94m3/hr

Assume 2-hr per cycle operation**,**

=1.94m3/hr*2hr=3.8 m3/cycle

If the tank is 75% full, the volume of mixer needed is

V=3.8m3/cycle/0.75=5.06 m^3

Sizing of Storage tank for water

Mass of water	900kg/hr
Material handled water	Density 1000 kg/m3
Material of construction	carbon steel

Volume of water =m/ ρ_w

The storage tank required for water is

= (900kg/hr +0.1*900)/1000kg/m3 =0.99m3/hr

Assume 2-hr per cycle operation**,**

=0.99m3/hr*2hr/cycle=1.98 m3/cycle

The required volume of storage tank is1.98m3

Sizing of hydrolysis reactor

Slurry to be processed	mixture of teff husk powder and water in with dilluteH$_2$SO$_4$
Density of liquid	1045kg/m3
Materials of construction	glass lined steel

Volume of reactants

(Vr)= (Mptm+0.1*Mptm)/ρs + (mH$_2$o+0.1*mH$_2$o)/ρw + (mH$_2$so$_4$) /ρH$_2$so$_4$

= (1658.05kg/hr+0.1*1658.05kg/hr)/942.25kg/m3+ (96kg/hr+0.1*96kg/hr)/1000kg/m3

+13.08kg/hr)/1840kg/m3

=1.93m3/hr+0.105m3/hr+0.007m^3/hr

=2.042m3/hr

Assume 3hr per cycle

=2.04m3/hr*3hr=6.12m^3/cycle

If the reactor is 75% full, the volume of reactor is

VR = 6.12m3/cycle/0.75

= 8.17m3

Storage tank for hydrolyzed sample,

Simply the volume of hydrolyzed sample (reactants leave from hydrolyzer (Vr=6.12m3), so the required volume for holding hydrolyzed sample is=6.12m^3

Sizing of Fermentation tank

Liquid to be handled	hydrolyser liquid
Density of liquid	942.5kg/m3
Material	carbon steel
Temperature of liquid	30^{o}C

Volume of liquid going to be fermented = (mH+0.1MH)/ ρs

= (1842.28+0.1*1842.28)kg/hr/942.28kg/m3

=2.15m3/hr

This process takes 72 hr per one cycle, so one cycle takes 24/72=0.33hrs per cycle

=2.15m3/hr*0.33hr/cycle=0.71m3/cycle

If 75% of tank is full, the required volume for fermenter is

V=0.71m3/cycle/0.75

$=0.95m^3$

Storage tank for Bioethanol

Liquid to be handled	Bioethanol
Density of liquid	790kg/m3
Temperature of liquid	25^0C
Materials of construction	carbon steel

Volume of the bioethanol (product) = $(m_{c2H5oH}+0.1*m_{c2H5oH})/ \rho_{c2H5oH}$

= (590.81 kg+0.1*590.81 kg/hr)/m3/790kg/m3

=0.82m3/hr

Assume 2-hr per cycle operation**,**

=0.12m3/hr*3hr/cycle=2.46 m3/cycle

The required volume of storage tank is 2.46 m3

Pump for delivering of hydrolyzed liquid to fermenter

Type	diaphragm pump
Head	3m
Liquid to be processed	hydrolyzed slurry
Density	942.25kg /m3
Temperature of liquid	25^oC

Materials of construction	carbon steel

Volume of hydrolyze to be pumped=mass flow rate/density

$$=1842.28\text{kg/hr}/942.25\text{kg/m}^3$$

$$=1.96\text{m}^3/\text{hr}$$

So, capacity of Diaphragm pump required is 1.96 m^3/hr

CHAPTER SEVEN

7. COSTING AND ECONOMICAL FEASIBILITY ANALYSIS

No matter how technically sound an engineering project is, it will fail if it is not economically feasible So that, the aim of this section is to present information regarding the economic feasibility for the production of bioethanol from teff husk. Hence, before initiating the development of a process to the plant scale, it is necessary to make an economic evaluation. Even if insufficient technical information is available to design a plant completely, we must still make an economic evaluation to determine if it is economically feasible. A project economically feasible when it is more profitable than other competing project, and financially feasible when management can raise the capital for its implementation. The economic evaluation of a process proceeds in several steps. These are:-

- Preparing a process flow diagram
- Calculating mass and energy flows
- Sizing of the required equipment
- Estimating the production cost
- Forecast the product sales price
- Estimating the return on investment

This economic evaluation is based on the utilization of 3527.08 ton of teff husk, and producing 2765 ton per year. The costing for this study is based on the determination of percentage of delivered equipment cost estimation, which is commonly used for preliminary and study estimates. The complete cost estimation of the plant is included into two main parts:-

- Total capital investment
- Total production cost.

7.1 Total Capital Investment

The capital needed to supply the necessary manufacturing and plant facilities is called the fixed capital investment and includes direct and indirect costs, while that necessary for the operation of the plant, in the initial phase, is termed the working capital. The sum of the fixed capital investment and the working capital is known as the total capital investment. The total capital investment is determined by percentage of delivered equipment cost estimation in this report.

Year	2014	2015	2016	2017
CEPCL	584.6	567.3	576.1	556.8

Table 7.1 Chemical Engineering Plant Cost Index

The index for 2018 is determined by extrapolation 2014= 576.1, 2015 = 556.8

$$2018 = X\ (2015-2014) / (556.8-576.1) = (2018-2015)/(X-556.8)$$

$$X=-57.9+556.8$$

$$=498.9$$

A. **Fixed Capital Investment (FCI)**

It is the capital needed to supply all manufacturing and plant facilities. FCI can also be defined as the total cost of the plant ready for startup. This includes:

Direct (manufacturing) fixed capital investment– the amount of money necessary for the installed process equipment with all auxiliaries needed for a complete process operation (e.g. purchased equipment cost, equipment installation cost, instrumentation and control cost, piping cost, electrical equipment and material cost, building (including services) cost, yard improvement cost, service facilities coat, land cost, etc.)

Indirect (nonmanufacturing) fixed capital investment: Construction overheads and all plant components which are directly related to the process operation. (E.g. engineering and supervision cost, construction expenses, contractor's fee, contingency fees, warehouse, laboratories, transportation, utility etc.)

Calculation for estimation of water storage tank cost

Previous, 2016

- cost (c1)=34500
- volume (v1)=76 m3
- index (I1)=576.1

Present, 2020

- Cost (C_2) = ?
- volume(v2)= 1.98 m3
- index(I2)= 498.9

- Exponent (n) is assumed to be 0.57

$$c_2 = c1\ ((v2/v1)^{n}\ (I2/I1))$$

$$=34500((1.98/76)^{0.57}\ (498.9/576.1))$$

$$=\$3735.70$$

Calculation for estimation of fermenter (jacketed and agitated reactor)

Previous, 2016

- cost(c1)=2520
- volume(v1)=15.14 m3
- index(I1)=576.1

Present, 2020

- Cost (C_2) =?
- volume (v2) = 0.95 m3
- index (I2) = 498.9
- Exponent (n) is 0.54

$C_{2=}\ C_1\ ((V_{2/}V_1)^n\ (L_2/L_1))$

$$=2520((0.95/15.14)^{0.54} * \ (498.9/576.1)$$

$$=\$450.35$$

And the rests are filled in the following table in the same manner.

Equipment	Capacity	Quality	Exponent	Cost($)
Storage tank for water	1.98m^3	1	0.58	3,735.70
Dryer	0.08m^2	1	0.6	4,109.68
Roller mill	0.52m^3(10kg/s)	1	0.6	1,085.90
Mixer tank	5.06m^3	1	0.6	3,506.66
Hydrolyzer	8.17m^3	1	0.54	1,564.04
Centrifugal separator	0.5m	1	0.67	461.16

Storage tank for hydrolyzed slurry	6.12m^3	1	0.57	7,107.53
Fermenter (jacketed & agitated reactor	0.95m^3	1	0.6	450.35
Boiler	-	1	0.6	1,137,870.57
Distillation column	0.32m, with 7plate	2	0.86	2,601.77
Condenser	2m^2	1	0.6	6824.5
Molecular sieve	0.32m^3	1	0.6	6604.4
Storage tank for bio ethanol	2.46m^3	1	0.57	4227.69
Diaphragm pump with motor	0.82m^3 /hr	1	0.6	3,367.78
Total				1,184,896.27

Table 7.2 Purchased equipment cost

Since the process of our plant is solid fluid processing, the fixed capital investment is calculated as the bellow

A Direct cost	Percentage (%)	Cost($)
Purchased equipment	100	1,184,896.27
Purchased equipment installation	39	462,109.57
Instrumentation and control	13	154036.5
Piping	31	367317.84
Electrical	10	118489.62
Building including service	29	343619.91
Yard improvement	10	118,489.62
Service facilities	55	651,692.94

Land	6	71,093.33
Total direct cost (TDC)		3,471,746.07
Engineering and Supervision	32	379,166.8
Construction expense and contractor fee	34	402,864.73
Contingency	36	426,562.65
Total indirect cost		1,208,594.118
Fixed capital investment(A+B)		4,680,340.25

Table 7.3 Estimation of fixed investment capital cost

But, we know that, TCI=FCI+WC, since working capital cost is (10-20) % of total capital investment

$$TCI = FCI + 0.15TCI$$

$$TCI = FCI/0.85 = 4,680,340.25/0.85$$

$$= \$5,506,282.65$$

B. Working Capital (WC): is the capital needed for the daily running of the plant. In other words, it is the additional investment capital needed over and above the fixed capital investment to start the plant, to operate it to the point when income is earned. This consists of the total amount of money invested in.

- Startup
- Raw material and supplies carried in stock
- Finished and semi-finished products in stock
- Accounts receivable and payable
- Cash kept on hand for monthly payment of operating expenses and Taxes payable.

It is estimated that working capital is approximately 15% of total capital investment.

Therefore, Working cost (WC) =0.15* TCI

$$= 0.15 * 5,506,282.65$$

$$= \$825,942.39$$

7.2 Total Production Cost

The determination of the necessary capital investment is only one part of a complete cost and evaluation estimate. The other important part is the estimation of the cost of operating the plant. The total production cost is generally divided into the categories of manufacturing costs and general expenses. All expenses directly connected with the manufacturing operation or the physical equipment of a process plant itself is included in the manufacturing costs. Total production cost is broken down into two: manufacturing cost and general expenses. The manufacturing costs are also subdivided into fixed operating costs, variable operating costs and plant overhead costs. The general expenses are involved in any company's operations. The total production costs are calculated on an annual basis in this project.

7.2.1 Manufacturing Costs (MC)

All expenses directly connected with the manufacturing operation or the physical equipment of a process plant itself is included in the manufacturing costs. These expenses, as considered here, are divided into three classifications as follows: -

1) Direct production costs,

2) Fixed charges, and

3) plant-overhead costs.

1. Direct production costs: Include expenses directly associated with the manufacturing operation. This type of cost involves expenditures for raw materials (including transportation, unloading, etc.) direct operating labor; supervisory and clerical labor directly connected with the manufacturing operation; plant maintenance and repairs; operating supplies; power; utilities; royalties; and catalysts.

2. Fixed operating costs (fixed charges):- Fixed operating cost are expenses which are practically constant from year to year and do not vary widely with changes in production rate. These are the bills that have to be paid whatever the quantity of "product" produced. Depreciation, property taxes, insurance, and rent require expenditures that can be classified as fixed charges.

3. Plant overhead costs:- are costs that comprise hospital and medical bills, general plant maintenance, cost of safety services; payroll overhead including pensions, vacation allowances, social security, and life insurance; packaging, restaurant and recreation facilities, salvage services, control laboratories, property protection, plant superintendence, warehouse and storage facilities, and special employee benefits .etc. (Peter et al, 1990).

A. Direct production cost calculation

A direct production cost comprises about 60% of total product cost.

1. Raw materials (l0-50% of total product cost)

2. Operating labor (10-20% of total product cost)

3. Direct supervisory and clerical labor (10 -25% of operating labor).

4. Utilities (10-20% of total product cost).

5. Maintenance and repairs (2-10% of fixed -capital investment)

6. Operating supplies (10 -20% of cost for maintenance and repairs, or 0.5-1% of fixed capital investment).

7. Laboratory charges (10-20% of operating labor).

8. Patents and royalties (0-6% of total product cost)

1. Raw Material Cost

Item	Quantity per year (kg)	Unit price per kg ($)	Total annual cost($)
Teff husk	3,527,802	$1.8*10^3$	6,348.75
Sulphuric acid (98%)	61,2114.4	0.275	16833.96
Yeast	291,049.2	0.72	209,555.42
Total			232,738.13

Table 7.4 raw material cost

2. Utility cost

Item	Quantity per year	Unit price	Cost($)
Water	$1*10^7$ (kg)	$1.805*10^{-4}$	1,805
Electricity	492264.4 (kwh)	0.027	13,291.13

Packing material(1L&2L container)	150,000	0.036 for 1L & 0.072 for 2L respectively	9.000
Total			24,096.13

Table 7.5 utility cost

From literature review Their net energy values ethanol production were within the range (4 to 10 MJ/L of ethanol) found by most researchers, we have taken the average (4+10)MJ/2=7MJ

3. Operating Labor cost

Types	Labors	Quantity	Salary per month for one person(Birr)	Total salary(birr)	Total annual salary(birr)
Skilled workers	General manager	1	8000	8000	96,000
	Technical manager	1	6000	6000	72,000
	Commercial manager	1	5500	5500	66,000
	Finance manager	1	4000	4000	48,000
	Production manager	1	5000	5000	60,000
	Secretary	1	1000	1000	12,000
	Electrician and mechanics	2	3000	6000	72,000
	Operator	4	3000	12,000	144,000

	Laboratorial	2	3000	6000	72,000
Unskilled workers	Messenger and time keeper	2	1000	2000	24,000
	Guard	2	1500	3000	36,000
	Cleaner	2	700	3500	42,000
Total					717,000

Table 7.6 operating labor cost

Then, since all cost dealt previously were in dollar, let us convert birr in to dollar (1dollar=27.7 birr) Cost of operating labor (COL) = 717,000birr*1$/27.7 birr=$25,884.48

4. Direct supervisory and clerical labor (10 -25% of operating labor).

Let us take (11%)

=0.11*COL

=0.11*25,884.4

8=$2,847.29

5. Maintenance and repairs [CMR] (2-10% of fixed -capital investment). We have taken (3%)

CMR=0.03*FCI

=0.03*$4,680,340.25

=$140,410.21

6. **Operating supplies** (10 -20% of cost for maintenance and repairs), we have taken (11%)

=0.11* CMR

=0.11*$140,410.21

=$15,445.12

7. **Laboratory charges** (10-20% of operating labor cost), we have taken 11%

=0.11* COL

=0.11*25,884.48=$2,847.29

8. **Patents and royalties** (0-6% of total product cost), average 3%

=0.03TPC

Hence, direct production cost (DPC) = (1+2+3...+8)

=232,738.13+24,096.13+25,884.48+2,847.29+140,410.21+15,445.12+2,847.29+0.03TPC

=444,268.65+0.03TPC

B. Fixed charges (FC) (10-20% of total product cost)

1. Depreciation (depends on life period, salvage value, and method of calculation-about 10% of fixed-capital investment for machinery and equipment and 2-3% of building value for buildings). Depreciation (10%FCI)

=0.1*$4,680,340.25

=$468,034.03

2. Local taxes (1-4% of fixed-capital investment), we have taken the average (1.2%) =0.012*FCI

=0.012*$4,680,340.25

=$56,164.08

3. Insurance (0.4-1% of fixed capital investment), average=0.007%

=0.007*FCI

=0.007**$4,680,340.25

=$32,762.38

4. Rent (8-12% of value of rented land and buildings), we have already purchased the land, so no need of renting land and building

Therefore, total fixed charge (FC)

=1+2+3=468,034.03+56,164.08+32,762.38

= $556,960.46

C. plant overhead cost (OHC)

Plant-overhead costs (50-70% of cost for operating labor, supervision, and maintenance, or 5 - 15% of total product cost) the average

= (5+15) % /2

=10% for TPC

=0.1TPC

Therefore, Manufacturing cost (MC)

=DPC+FC+OHC

=444,268.65+0.03TPC+$556,960.46+0.1TPC

=1,001,229.11+0.13TPC

7.2.2 General Expense (GE)

Besides to manufacturing costs, general expenses are involved in any company's operations. These general expenses are administrative expenses, distribution and marketing expenses and research and development expenses.

General expense = Administrative cost+ Distribution and selling costs + Research and development costs + financing (interest).

Administrative costs (about 15% of costs for operating labor, supervision, and maintenance, or 2-6% of total product cost).

Distribution and selling costs (2-20% of total product cost).

Research and development costs (2-5% of every sales dollar or about 5% of total product cost).

Financing (interest) (0-10 % of total capital investment)

1. Administrative costs (about 15% of costs for operating labor, supervision, and maintenance, or 2-6% of total product cost).

=0.03*TPC

2. Distribution and selling costs (2-20% of total product cost), let us take35%

=0.05*TPC

3. Research and Development cost [R&D] (5%TPC)

=0.05*TPC

4. Financing (interest) (0-10 % of total capital investment), let us take3% =0.03*TCI=0.03*$5,506,282.65

=$165188.48

Therefore General expense (GE)

=1+2+3+4

= 0.03*TPC+0.05*TPC+0.05*TPC+$165188.48

=0.13*TPC+165188.48

Then, Total Production Cost (TPC) =MC+GE

TPC =1,001,229.11+0.13TPC +0.13*TPC+165188.48

=1166417.59+0.26TPC

TPC=$1166417.59/0.74

TPC=$1,576,239.98

7.3. FINANCIAL EVALUATION

7.3.1. Profitability

Based on the projected profit and loss statement, the project will generate a profit throughout its operation life.

Production capacity=3.5*106litre/yr

Mass of the product =density*volume

=790kg/m3*3.5*106litre/yr*m3/1000litre

=2,765,000kg/yr

Unit price cost=TPC/Plant capacity

=1,576,239.98$/yr / (2765000 kg/yr)

=$0.57/kg

=$ 0.57/kg, but since the current price of bioethanol is $1.076/kg so to get good profit we decide to sell by this price

Selling Price

Total income = selling price of product × production capacity

=$1.076 *2,765,000kg/yrkg

=$2,975,140

Profit before tax=Total income-Total production cost

=$2,975,140-$1,576,239.98

=$1,398,900.02/yr

The standard tax will be used (35%)

=0.35*$1,398,900.02/yr

=$489,615.00/yr

Then profit after tax is, =profit before tax-tax

=$1,398,900.02/yr-489,615.00/yr

= $909,285.01/yr

Net Profit after tax is =$909,285.01/yr

❖ **Rate on investment (ROI)**

Before tax=profit before tax/ (FCI)*100%

= (489,615.00/ 4,680,340.25)*100%

=10.46%

After tax=net profit after tax/ (TCI)*100%

= ($909,285.01/5,506,282.65)*100%

=16.51%

❖ PAY BACK PERIOD

=FCI/ (net profit +depreciation)

=4,680,340.25/ (909,285.01 +468,034.03)

= **3.4**, hence this project is acceptable!

Chapter Eight

8. Site selection plant layout

Co-location of bio ethanol plants with coal-fired power plants may provide an opportunity for early deployment of bio ethanol technologies. Integration of the bio ethanol operations with the power plant could benefit both facilities (purchasing of steam from the power plant and sharing of overhead costs such as maintenance for Bahrdar waste gojam zone locations are interest this because of the vast teff husk resource available for bio ethanol and bioenergy production concentrated in the Ethiopia. A superior bio ethanol plant site encompasses many factors. Proximity of feed stocks, good road and rail access, utility availability and space for equipment and truck movement are necessary. Other considerations include a qualified and/or trainable labor force, as well as community facilities that are capable of attracting and retaining top management personnel who may come from outside the area. The site selection criteria used to screen the ten sites include the following general categories.

- ✓ Adequate biomass feedstock within a reasonable transportation distance
- ✓ Access to a large coal fired power plant
- ✓ Cost of coal (higher is better for the bioethanol plant lignin value)
- ✓ Existing or planned ethanol or agricultural processing facility at the site
- ✓ Infrastructure that may reduce the bioethanol plant cost (steam supply or wastewater treatment, for example)
- ✓ Access to good road and rail transportation
- ✓ Access to a local ethanol market
- ✓ Community services needed to support the ethanol plant
- ✓ Other advantages of the site

Each site selection criteria is assigned a maximum score that indicates the relative importance of that criterion when selecting an appropriate site for a bio ethanol plant. Each criterion is described below. The strengths of the site are the abundance of teff husk stover in the area, main line track service and a relatively low cost of coal, which should result in higher value for the ethanol plants lignin. The Bahrdar waste gojam site suffers from a lack of nearby interstate highway access and the distance to the nearest major bio ethanol market.

CHAPTER NINE

9. Conclusion & Recommendation

9.1 Conclusion

Generally production of bio ethanol is one of the most important products as fuel and many other uses as industrial additive. Mainly it can solve Petroleum a shortage, environmental problem comes from emissions of harmful gases and from byproducts of gasoline and diesel, Scarcity of non-renewable natural resources, this replace by using renewable natural resource. Bio Ethanol production is the most economical and efficient process. Lignocelluloses material (Hemicelluloses, cellulose and lignin) are usually hydrolyzed with a chemical process (acid) or biological (enzyme) attack. Production of bioethanol from teff husk pass through for major process like pretreatment, hydrolyzation, fermentation, and distillation. We can apply the characteristic of both sample (ash, carbohydrates, and moistures content) and product (done physically (color and volatility). For each process the experimental done and the result obtained is mentioned and discussed in this thesis project. And also, this process we apply material and energy balance concept to make the process efficient and effective and to investigate its productivity we submit an application of process economics and profitability measures. Finally we can investigation of sufficient fuel bioethanol.

9.2 Recommendation

As Ethiopian country consider whether and how to stimulate bio ethanol production in their states, there are a number of immediate steps that can be taken. The following is a short list of potential actions would be taken:

- Educational -It all begins with information. Work with government agencies and bio ethanol advocacy groups to educate stakeholders and the public about the opportunities and benefits of ethanol.
- Police exploration-Work with state and local government officials to explore and coordinate potential policies to support in-state bio ethanol production. Inform policy-makers of the economic growth that ethanol project development can foster, both directly, through job creation and increased tax revenue, and indirectly, through development of complementary industries. Consider policies that have aided bio ethanol development in other regions, including production incentives, tax credits, and low interest loans.
- Feasibility analysis- Locate problematic/opportunistic waste streams. Assist potential developers with site assessments and feasibility analysis.
- Outreach - Cultivate community leadership. Reach out to community members and stakeholders and help them come together. Find people with an economic interest in ethanol development. Work with them to put together an ethanol commission. Involve potential bio ethanol developers, community members, farmers, energy experts, environmental advocates, and other interested parties.

Reference

[1]. Alemayehu Gashaw Mengesha (May 2015), Effect of pH and Substrate Concentration on Ethanol Production from Potato Peel Waste Using Saccharomyces cerevisiae, PPN (2, 7, 14).

[2]. Biochemical conversation process (Solomon et al. 2007,)

[3]. Consumption of teff in Ethiopia (Baye, 2014),

[4]. Enzyme hydrolysis of lignocellulosic material (Sun and Cheng, 2002),

[5]. Feedstock for bioethanol production (cellulosic ethanol, 2010),

[6]. Genetic Engineering to express heterogonous cellulose (Lynd et al, 2005)

[7]. Gluten Izmirlioglu (August 2010).Ethanol production from waste potatoes Mashes by using Saccharomyces cerevisiae, pp (iii, 54).

[8]. Pretreatment of lignocellulosic material (Nirbhay Gupta, 2008)

[9]. Wondale Mokenone (Nov 2012). Ethanol production from selected fruit peel waste.PPN (2430)