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COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

**VALORIZATION OF COFFEE HUSK TO BIOETHANOL BY
USING SEPARATE HYDROLYSIS AND FERMENTATION
METHODE**

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DECLARATION

We declare that this thesis is our original work prepared by under the guidance of Mr. Getachew our advisor we have improved our practical skill, theoretical knowledge and entrepreneurship skill. We also declare that it has not been previously or currently submit for Wolikite University

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ABSTRACT

Coffee husk considers as one of the agricultural waste lignocellulose biomass that contain high amount of cellulose In Ethiopia 192,000 metric tons of coffee is husk cast adrift as by product per year. Thus, in compliance with the concept of suitable for development, innovative techniques and products for the profitable and adequate use of this type residue are being sought. Several research works presenting proposals for such endeavors have been published in the literature and reviewed here in. Furthermore, the aim of this work is valorization of coffee husks to bioethanol by using separate hydrolysis and fermentation methods, which is critically used as replacements for renewable sources of energy and to minimize environmental pollutions too. This method was accomplished by four major experimental procedures, which were pretreatment, hydrolysis, fermentation and distillation processes. There were two parameters and 6 lab experiments exposed in the laboratory work depending on the H_2SO_4 concentration and size difference in the hydrolysis step. The effect of these parameters was analyzed using Microsoft Excel. The results showed that the content of sugars increased as the acid (H_2SO_4) concentration increased from 1% - 3 % and decreased as the acid concentrations increased from 3 % up to 5 %. At the optimal acid concentration (3%, H_2SO_4), the sugar yield obtained was 50.18 % from the coffee husk. This sample was further investigated to produce bioethanol and the ethanol yield from this experiment was 68.28 %. The product is clear and colorless liquid. The yield of each experiment is calculate and characterize by pH Value, physical and chemical properties. Then, higher efficiency was selected. Based on this, the economically feasible bioethanol plant with annual producing of 5,000,000liters per year was estimated and its site location is Jimma area due to availability of raw material and other some facilities.



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ACRONYMS AND ABBREVIATION

CHs	Coffee Husks
CP	Coffee Pulp
C₂H₅OH	Ethyl Alcohol
H₂SO₄	Sulfuric acid
NaOH	Sodium Hydroxide
HCl	Hydrochloric acid
C₆H₁₂O₆	Glucose
CO₂	Carbon dioxide
M	Metal
QM	Heat of media
Q_{gen}	Heat of generation
Kpa	kilo Pascal
GEC	General Expense Cost
EC	Equipment Cost
WC	Working Capital
FCI	Fixed Capital Investment
CP	Specific Heat Capacity
FC	Fixed Charges
LCW	Lignocellulose Waste
SHF	Separate Hydrolysis and Fermentation



CHAPTER ONE: INTRODUCTION

1.1. Background

Coffee beans deemed as a commodity ranking second next to petroleum in terms of currency traded worldwide. The global coffee production per year on average accounts to approximately 7 million metric tons [1]. The top five countries that produces coffee in 2015/16: Brazil, Vietnam, Colombia, Indonesia and Ethiopia are produces; 2592000, 1650000, 810000, 660000, 384000metric tons respectively [2]. Ethiopia is one of the coffee producer countries in the world. Jimma zone produces about 70% of coffee in Ethiopia. Coffee generates large amount of coffee by-products/residues during processing which considered as the major solid wastes. Coffee husks are the major solid residues from the handling and processing of coffee, since for every 2Kg of coffee beans produced, approximately 1kg of husks are generated [3].

In Ethiopia 192000metric, tons of coffee husk cast a drift as by-product per year. Coffee grounds are highly pollutant due to the presence of organic material that demands a great quantity of oxygen in order to degrade. Proposed alternative uses for coffee husks include employing this solid residue as a supplement for animal feed, direct use as fuel, and fermentation for the production of a diversity of products (enzymes, citric acid and flavoring substances), use as a substrate for growth of mushrooms and use as adsorbents. Valorization of this coffee husk to some valuable products such as bio-ethanol can used for environmental pollution prevention as well as for alternative source of energy. Therefore, valorization of this waste indicates that excellent potential of residue utilization for valuable product production that it does not involve costs related to raw material growth.

The development of fuels (bioethanol) from this coffee husks has many advantages in terms of energy and environmental issues bioethanol as energy has been used throughout man's long history. Ethanol was one of the most common lamp illuminants used in 1850s and approximately 90 million gallons ethanol produced in the United States. However, due to the tax burden on ethanol to assist in financing the civil war and the cheaper price of kerosene, it quickly replaced ethanol as the premier illuminant in 1861. Then in 1906, the alcohol tax lifted, which transformed the interest in ethanol and in 1908, Henry Ford designed the automobile car "Model T" to run on ethanol.



By 1914, the production of ethanol had recovered slightly and reached 10 million gallons. However, in 1919, due to the development of petroleum as fuel, the use of ethanol as fuel decreased again. This veto was ended in 1933 and by the early 1940s, the production of ethanol rebound again when it was used during World War II for fuel and to make synthetic rubber. During this period, about 600 million gallons of ethanol produced annually in the U.S. At the end of World War II, demand for ethanol diminished and continued to decline for the next two decades, mostly due to inexpensive petroleum imports [4].

Currently first generation bioethanol production processes utilize more simply degradable biomass feed stocks such as cereals (corn or grain). Conversely, the utilization of these agricultural crops absolutely for energy production is heavily conflicting with food and feed production. Second-generation bioethanol can be produced from lignocellulose biomass. These wastes (LCW) states that plant biomass wastes that composed of cellulose, hemicellulose and lignin. These assembled into different categories such as wood residues, grasses, waste paper, agricultural residues (including straw, coffee husk, peelings, cobs, stalks, nutshells, and nonfood seeds), food industry residues and municipal solid wastes [4].

At present, the second-generation bio-products such as bioethanol, biodiesel and methane from lignocellulose biomass are progressively being produced from wastes rather than from energy crops because the latter plays for land and water with food crops that are already in high demand. The development of fuels (bioethanol) from coffee husks has many advantages in terms of energy and environmental issues. This bioethanol fuel has received increased attention in recent years due to its reducing of greenhouse gas emissions and for decreasing global reliance on petroleum products. Bioethanol is widely used as a biofuel due to the following reasons: (1) bioethanol has high oxygen content and octane number; (2) bioethanol is non-poisonous; and (3) bioethanol is environmentally approachable since it decreases pollutant emissions such as carbon monoxide, Sulphur and nitrogen oxides. *Saccharomyces cerevisiae* has been the most usually used microorganism for the bioethanol production by the fermentation of different feedstock rich in sugars [5].



1.2. Statement of problem

Coffee produces large amount of coffee by-products/coffee husk during dry methods. Most of these husks were disposed to the environment and this represents a serious environmental problem mainly due to the high content of tannins and phenolic compounds in the coffee husk. Some people burn the generated coffee husk, some also used as animal feed while others disposes it on the field. It is great important that converting to value added product such as bioethanol instead of disposing to rivers or simply burning of these coffee husks.

In other case, in earlier time, the world economy has controlled by technologies that depend only on fossil energy, such as petroleum, coal, or natural gas to produce fuels, chemicals, materials and power. Since these fossil fuels are not renewable sources of energy, this can cause energy limitation as well as environmental pollution by increasing concentration of CO₂ in the atmosphere and concerns over global warming. So, an alternative renewable energy source is required to solve such problem. One of the most effective, feasible way and non-food competitive feedstock raw material that needed for the production of alternative renewable source of energy can be valorization of coffee husk residues to bio ethanol. The BSc. research done to valorize these coffee husks to valuable product bioethanol. In order to solve those (environmental pollution and to get renewable source of energy) problems we produce bioethanol from coffee husk with quality for the purpose of energy source.

1.3. Objectives

1.3.1. General objective

The general objective of this research is valorization of coffee husk to bioethanol by using separate hydrolysis and fermentation method.

1.3.2. Specific objective

- Characterization of raw material.(ash content, moisture content, volatile and fixed carbon)

- Evaluate yield of bioethanol by varying size of sample and diluted sulfuric acid concentration in hydrolysis stage.



-
- Characterization bio-ethanol produced from coffee husk by using physical and chemical method
 - Evaluation of material and energy balance
 - Evaluation of economic analysis.

1.4. Significant of research

The project work carried out with the objective of hydrolysis of glucose from coffee husk and produce bioethanol by using fermentation. The project work aimed at studying the replacement of those nonrenewable sources of energy. The product of bioethanol from environmentally friendly product of coffee husk has a dual advantage of using locally source raw material that can be grown and generating wastes. The significance of this study is look in different dimension however some of the main point will be explained in the following,

- Now a days the case of global warming become increased so this research will led to use other source which has low consumption of CO_2 and other greenhouse gas's
- Valorization of coffee husk to give a renewable form of energy source such as bioethanol so this research will use for specialist in air pollution study
- To announce the technology
- To create a new job for employment
- To show the direction to everyone to be entrepreneur

1.5. Scope of the study

The scope of the project work in valorization of coffee husk residues to bioethanol using separate hydrolysis and fermentation method using the material in carrying out the project and testing, analyzing the result obtained. The project is embrace quality and cost effectiveness; our primary scope starts with preliminary identification of feedstock for bioethanol manufacturing.



CHAPTER TWO: LITERATURE REVIEW

2.1. Coffee bean

Coffee is one of the most popular and important beverages in the world. It grows commercially in rapid way over the last years. In general, around 25 million small producers rely on coffee for their living [7]. Ethiopia is one of the coffee producer's countries in the world. Jimma zone produces about 70% of coffee in Ethiopia. Coffee generates large amount of coffee by-products/residues during processing which considered as the major solid wastes [8]. For every 2kg of coffee beans produced, approximately 1 kg of husks generated. In Ethiopia 192000 metric tons of coffee husk generated per year as by product. There has been some significant investigation of coffee husk as a substrate for ethanol production however, it's not clearly done by the method of separate hydrolysis and fermentation method and therefore its potential can be estimated from other often-used substrates like sugarcane bagasse. It is estimated that in the later year sugarcane bagasse in Ethiopia had the leading potential for ethanol production. Since Ethiopia being a leading producer of coffee, it's also possible to utilize this coffee husk to bioethanol in a very high amount instead of sugar cane for another application.

2.2. Current Over view of Bioethanol production

2.2.1. Worldwide current status of bioethanol production

Current study indicates that; the most dominated bio-fuel is bio ethanol. Its worldwide production shows an upward trend with a higher increase over the last 20 years [9]. Since 2005, global production ability for bioethanol fuel was showed around 45 billion liters per year. This shows approximately 15% annual growth between the years of 2000 and 2005 [10]. After one year in 2006, this value was enlarge to 49 billion liters. Brazilian and Americans was produce 75% of the total world ethanol productivity with 40% Brazilian and 35% American, followed by Asia/Pacific and Europe/Africa with respective values of 15 and 10% [14]. Based on the current status fuel ethanol production will be forecast to have the strongest increase in the Brazilian and Americans, where the production rate is estimated to rise to around 75 and 80 billion liters by 2020. This indicates around 45 billion liters increase in the estimation period than the current production rate.

In Asia it was increase to 10 billion liters throughout the same period, in Europe, there is a strategy of bio-fuels share in the transportation sector, and the production will rise highly. Therefore, the total world ethanol production in 2020 forecast to reach over 120 billion liters [7].

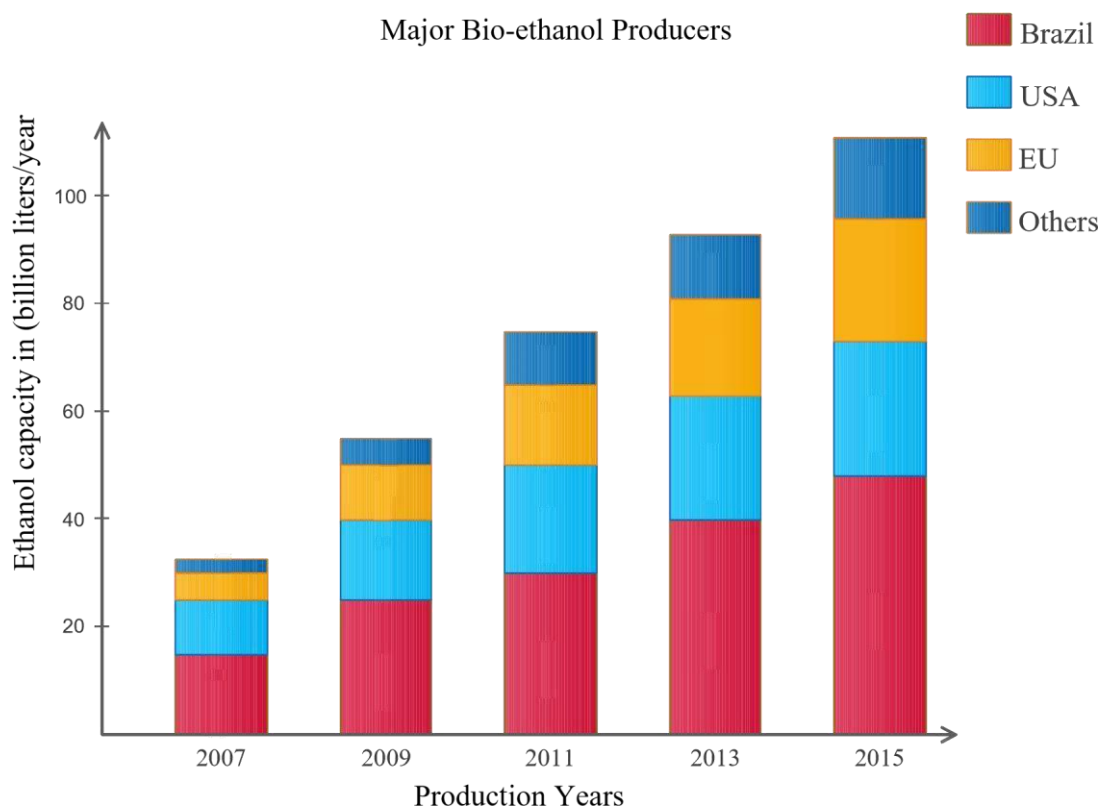


Figure 2. 1 Annual bioethanol production by main procedure [7]

One of the methods of producing bio-ethanol is microbial transformation of lignocellulose material through fermentation process [11]. This production process can be consisting conversion of biomass to fermentable sugars, fermentation of sugar to ethanol and the processes of the separation and refining of the ethanol [10]. In the international current mindfulness for the use of bioethanol to replace petroleum and generation of power along with sugar mill and other plants can have led to setting up of number of ethanol plants and co-generations [8]. In Ethiopia, there are different sugar industries like Fincha, Metehara and Wonji which controlled and managed by Sugar Development Agency (SDA). From this molasses can be produce as byproduct in which ethanol can takes in largest part, but its consumption must attract the attention of the government policy makers in order to utilize as a bioethanol.



Bioethanol or biofuel is ethanol-based products that can route into liquid fuels for transport purposes.

2.3. Feedstock for BioEthanol Production

Bioethanol can be produce from any biological feedstock that have high amount of sugar or materials that can be renewed in to sugar such as starch and cellulose. Many different feedstock for production of bioethanol can be divided in to sugary, starchy and cellulosic feed stocks that may additional convert in to simple sugars that are prepared for fermentation. Corn, wheat, barley and other cereals are usual feedstock containing starch types in their kernels. Starch are relatively informal to convert into sugar and then by fermentation into ethanol [12]. There are also other feedstock's that can be used for production of bioethanol from biomass, which comprises large amount of cellulose and hemi celluloses such as: agricultural wastes, forest residues, municipal solid wastes, crop residues and other lignocellulose materials that can be converted to simple sugars. This kind of conversion is to a certain degree difficult than conversion takes place in starch. Lignocellulose material is the main component of the plant cell walls and is mainly composed of cellulosic material (40– 60% of the total dry weight), hemicellulose material (10– 20%), and lignin (10–25%). Since this lignocellulose, biomass consists some compositions it can convert to bioethanol by some consecutive procedures. First, the lignocellulose biomass pretreated by steam or chemical and hydrolyzed by dilute acid or enzyme. Then the released sugars can be fermented using yeast as catalyst and separation will be apply for further purification of the bioethanol [13]

2.4. Compositions and Properties of Coffee Husk

Coffee husks are lignocellulose biomass, which are compose by the coffee berry outer skin, the pulp and the parchment, largely resulting from the coffee dry processing. Coffee husks are rich in total carbohydrates (62%), proteins (5.2%), fibers (15.8%) and minerals (5.7%). Generally, the chemical composition of coffee husk summarized in table 2.1 below:



composition of coffee husk (% dry matter)	
Total carbohydrate	58-85
Cellulose	53
Hemicellulose	10
Lignin	11
Protein	8-11
Minerals	3-7
Lipids	0.5-3

Table 2. 1 chemical composition of coffee husk [12]

Coffee husks are agricultural waste that are abundant, renewable and cost less energy sources in coffee growing counties (Ethiopia, USA, Vietnam, Brazils, and Uganda). These wastes gathered every year in large quantities, causing environmental as well health problems [8]. However, due to their chemical composition based on sugars and other compounds of interest, it could be develop for the production of a number of value added products, such as ethanol, food additives, organic acids, enzymes, and others. Therefore, in addition the environmental problems caused by their accumulation or removal in the environment, the non-use of these materials creates a loss of potentially valuable resources. Some important properties relating to the current conversion of coffee husk biomass to important fuels. Some of them listed below:

Bulk density (BD): Bulk density states that the weight of the material per unit volume of the container when biomass particles are put into a container. It is an important physical property of fuel which influences that the treatment and flow characteristics as well as energy density of the fuel. For biomass, bulk density is usually expressed on an oven dry weight (MC=0%) basis with corresponding symptom of moisture content (MC). A study on agricultural deposits of Uganda shows that coffee husk has the highest bulk density (225-275 kg/m³) compared to maize cobs, rice husk, groundnut shells and bagasse.



Moisture content (MC): The MC of biomass is the amount of water in the material expressed as a percentage of the material's weight. It may be stated as a percentage of total wet mass (wet basis), percentage of dry mass (dry basis) and percentage of dry-and-ash free mass (dry and- ash free basis) of the material. The basis on which the MC is measured must always be identified because it affects the value of biomass as fuel. MC considerably affects the net heating value of the fuel. The higher the MC the lower the heating value of the fuel because some of the energy is consumed in boiling the water. In energy applications, this water leaves the ignition products as steam and latent heat not recovered. A study on agricultural residue in Uganda displays that coffee husk has a MC of 14.073% (wb) [11]. A study in Brazil also shows that coffee husk has a MC of 13.1% (db). On the other hand, a study in Ethiopia shows that coffee husk (dry process) has a MC 12% (wb); whereas coffee husk (wet process) has a lower MC (10% wb).

Volatile matter content (VM): Volatile matter in biomass fuel constitutes all the liquid, tarry residues and low molecular weight gases which start to discharge after drying, leaving solid char in thermochemical processes. It considerably affects the fuel heating value, as it is a combustible portion of the fuel. High volatile matter indicates high heating value. Biomass typically has VM content up to 80% however coal has low VM (<20%) or in the case of anthracite coal, a negligible one. A study in Brazil showed that coffee husk has VM of 73.2% (db). Although, a study in Tanzania indicated a considerably higher value of 83% (db). Another study in Uganda indicated still higher value of 89.57% (db). A study in Ethiopia specified that coffee husk has VM of (65-72%). This suggests that coffee husk is easy to explode and suitable for large-scale thermo-chemical conversion [14].

Fixed carbon content (FC): Biomass may be approximately divided into two parts, combustible and non-combustible. The combustible part constitutes VM and FC, while the non-combustible portion constitutes moisture and ash. The heating value of a fuel is generally, the demonstration of carbon and hydrogen content of a fuel. Thus, FC is the most significant constituent of a fuel. FC content is usually estimated as a "difference". That is to say, all the other constituents subtracted from 100% and the remainder is assumed FC content. A study in Tanzania demonstrated that coffee husk has a FC content of 14.3%. Conversely, a study in Brazil specified a considerably higher value of 23.1% [14].

Ash content (Ash): Ash refers to the inorganic component or mineral matter, which remains as a deposit after complete combustion of the fuel. The total ash content as well



as the chemical composition of the ash are vital in thermochemical conversion. Ash, being incombustible component, tends to poorer the heating value of a fuel. Moreover, this, low melting temperature ash (with high alkali metal content) can cause various problems including slag and blockage due to sintering and accumulation in high temperature operations. Normally, coffee husk has low ash content but the ash has low melting temperature which is attributed to the high contents of K_2O (36-38%). An ash content as low as 2% (db) described from a study in Tanzania, and a value of 3.7% (db) informed from a study in Brazil. However, a small percentage higher value (69% wb) reported from a study in Uganda

2.5. Methods of Bioethanol production

There are two primary ways of producing fuel ethanol from cellulosic feedstocks:

1. Thermo-chemical conversion process
2. Separate hydrolysis and fermentation (SHF) methods

2.5.1. Thermo- chemical conversion

This process route includes production of syngas using gasification of the biomass, and fermentation or catalytic synthesis of the syngas to produce ethanol. The process begins with biomass gasification where, under a controlled oxygen supply, cellulose, hemicelluloses, and lignin converted to synthesis gas (syngas), primarily CO , CO_2 and H_2 . This syngas can be convert into ethanol either through catalytic synthesis; biomass gasification offers an attractive alternative system for producing cellulosic ethanol. Although gasification reactions can take many forms, these processes defined by cranking up the temperature to between 650 0C and 1,400°C. [14]

2.5.2. Separate hydrolysis and fermentation (SHF) methods

The technology of ethanol production from biomass feed stocks 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 those are water-insoluble.[14] For production of ethanol from cellulosic feedstocks, four major unit operations are required:



2.5.2.1. Pretreatment:

The goal of pretreatment process is to remove lignin and hemicellulose, reduce the crystallinity of cellulose and increase the porosity of lignocellulosic materials.

Objective of coffee husk pretreatment: -

- Improve the formation of sugar or the ability to subsequently from sugar by hydrolysis.
- Avoid the degradation or lose of carbohydrate.
- Avoid the formation of byproducts that are inhibitory to the subsequent hydrolysis and fermentation process.
- It is cost effective.
- To reduce the level of impurities
- To obtain better performance & yield
- To reduce scale formation

Pretreatment method can be roughly divided into different categories; physical (milling and grinding) and chemical (alkali, dilute acid and organic solvent), biological or composition of these.

1. Physical pretreatment: - Lignocellulosic biomass can be pulverize by chipping, grinding, shearing or milling. The goal of pulverization is to reduce the size of the particle to increase the surface area leads to improve cellulose hydrolysis. In this method ball mill used for breaking the crystalline structure of cellulose. Physicochemical pretreatment Steam explosion is the most commonly used method for pretreatment of lignocellulosic material. In this method, biomass treated with high-pressure saturated steam that helps to materials explosive decomposition.

2. Chemical pretreatment:- Chemical pretreatment involves the depolymerization lignocellulosic material with chemical agents such as acid, inorganic solvent, alkali and peroxides. Acid pretreatment used to breakdown hemicellulose to monomeric sugar and simultaneously remove the lignin. In this method, we use sulfuric acid. It has the following advantages.

- Get high yield of hemicellulose sugar.
- Remove lignin and expose.
- Remove heavy metals from the raw materials.



Alkali pretreatment used to break the bond with cross link lignin and carbohydrates, thus leads to the increasing porosity and increase the internal surface area of the biomass as well as decrease the crystallinity of cellulose the biomass matrix, resulting the improvement of susceptibility of the remaining polysaccharide to enzyme attack during hydrolysis.

2.5.2.2. Hydrolysis:-

Hydrolysis is a process where carbohydrates are convert to simple fermentable sugar. This facilitated through the pretreatment process, which changes the structure of biomass, thus allow the enzyme or chemical to enter its internal part. Hydrolysis is essential before fermentation to release fermentable sugar.in this process, cellulose cleaved to glucose, while hemicelluloses result in several pentose and hexodes. The hydrolysis step can be perform in different ways such as acid or enzymatic hydrolysis.

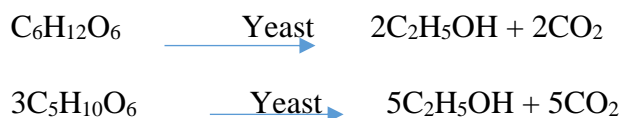
Acid hydrolysis generally use sulphuric acid or hydrochloric acid followed by dilution with water to convert the substrate into sugar. This process provides a complete and rapid conversion of cellulose to glucose and hemicellulose to 5-carbon sugars with little degradation. **Enzymatic hydrolysis** can occur under mild condition since enzymes are temperature and pressure sensitive and has two advantages. 1 Low utility cost since there is low corrosion and low toxicity of the hydrolysates. 2 Environmentally friendly processes. The degradation of cellulose to glucose in enzymatic hydrolysis catalyzed by specific cellulolytic enzymes

2.5.2.3.Adjustment of PH

Before addition of any microorganism to the diluted hydrolyzed sample, pH of these samples has to be adjusted. Otherwise, the microorganism will be die in hyper acidic or basic state. A pH of around 5.0 - 5.5 will maintain. The hydrolyzed samples were primarily check for pH using a digital pH meter. The pH then adjusted to 5.0 - 5.5. When the pH went below 5.0 - 5.5, sodium hydroxide solution was added drop wise to the flask with constant stirring until the pH reaches to a range of 5.0 - 5.5. When the pH went beyond 5.0 - 5.5, concentrated sulfuric acid was added drop wise to maintain the pH in the range.

2.5.2.4.Fermentation:

Fermenting microorganisms used for the conversion monomeric sugar to ethanol. The microorganism that used in fermentation process is fungi called saccharomyces cervisia, which has a superficial power to convert glucose to ethanol under anaerobic condition.



The glucose produced from the hydrolysis described above fermented with yeast to produce ethanol [13, 14].

Factors affecting rate yeast fermentation here are many factors that could affect the rate of yeast fermentation are

- ✓ Type of carbohydrate
- ✓ Concentration of carbohydrate
- ✓ Ethanol concentration
- ✓ PH, and
- ✓ Temperature – Effect of sugar concentration

Effect of pH: - The PH is the measure of acidity or alkalinity of aqueous solution expressed on scale of 1-14. Neutral is pH value of 7 PH 1-7, is acid and pH 7-14 is alkaline. The pH is the most conveniently measured with test paper that color change according to the pH of the solution being test Control of pH during the mashing and fermentation processes is important for two reasons the growth of harmful bacteria is retarded by acid solution and yeast will grow only in an (slightly acid solution). Generally, distiller's yeast shows a broad pH optimum from 4 to 5. The development of bacteria is severely repressed at pH value under 5. The acid most commonly used is sulfuric acid, although any mineral acid is perfectly suitable. Further, yeast can tolerate as low pH as without permanent damage.

Effect of temperature:- As heat energy is liberated during fermentation of sugar by yeasts, there is always an increase in temperature and cooling of fomenters is required, and, therefore, it is desirable to use temperature. Most strains have a temperature growth optimum of 30 – 35°C. However, the optimum fermentation temperature at a low alcohol concentration is often slightly higher (38°C), but alcohol tolerance is improved at reduced temperature. *S. Cerevisiae* strains having 37°C as optimum temperature for ethanol production have been select. Exposure to higher temperature results in excessive enzyme degradation and loss of yeast viability. Yeast can be stored inactive at low temperatures (above 0°C) and readily revived.



2.5.2.5. Distillation

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-distil during distillation. This means that proportion between two materials, in this case, ethanol and water can be change, and still, there are two materials in layers, the liquid and the vapor layers. Ethanol separated from water when its boiling temperature attained.

2.5.2.6. 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 mix with gasoline. Consequently, they separate into two phases, ethanol phase and gasoline phase. It is easy to imagine that this inhomogeneous fuel is not acceptable. Thus, dehydration can be another issue [15]. For the ethanol to be usable as a fuel, water must be remove. Most of the water removed by distillation, but the purity is limited to 95-96% due to the formation of a low boiling water ethanol azeotrope. For blending with gasoline, purity of 99.5 to 99.9% is required, depending on temperature, to avoid separation. Currently, the most widely used purification method is a physical absorption process using molecular sieves and another method is azeotropic distillation.

2.5.2.7. Molecular sieves

There is a lower bound on the fraction of ethanol entering the molecular sieve (0.8). Adsorption takes place at 95 °C. 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 saturate with water after a period and is then regenerate.

Hence, there are usually two sieves being operate in parallel – one saturated with water while the other is being regenerated (or dehydrated) using air under vacuum. Heat exchanger heats air with an assumed relative humidity of 70% at 20 °C to 95 °C. The air at the outlet of the dehydrating molecular sieve is cool down to 25 °C in heat exchanger and this stream leaves this exchanger saturated with water at 25 °C [16].



2.6. Bioethanol and Its Application as a Fuel

Ethanol, also known as ethyl alcohol with the chemical formula C_2H_5OH , is a flammable, clear, colorless and slightly toxic chemical compound with acceptable odor. It can be produced either from petrochemical feeds tocks by the acid-catalyzed hydration of ethane, or from biomass feed stocks through fermentation. On a global scale, synthetic ethanol accounts for about 5-10% of total production while the rest is produced from fermentation of biomass mainly sugar crops, e.g. cane and beet, and of grains (mainly corn) [17]. Ethanol as a neat fuel or even in the blended form with gasoline has a long history as automotive fuel. Fossil fuels were predominantly use for automobile transportation throughout the last century, obviously due to their lower production cost. As an automotive fuel, hydrous ethanol can be use as a substitute for gasoline in dedicated engines. Anhydrous ethanol, on the other hand, is an effective octane booster when mixed in blends of 5% to 30% with no engine modification requirement.

2.7. Properties of bioethanol

2.7.1. Physical properties

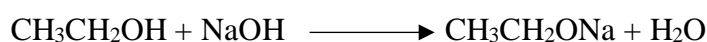
Ethyl alcohol under ordinary conditions is a volatile, flammable, clear, colorless liquid. Its odor is pleasant, familiar, and characteristic, as is its taste when suitably diluted with water. The most amazing property of ethanol is the volume shrinkage that occurs when it is mix with water, or the volume expansion that occurs when it is mixed with gasoline.

2.7.2 Chemical Properties

The chemistry of ethyl alcohol is largely that of the hydroxyl functional group, namely, reactions of dehydration, dehydrogenation, oxidation, and esterification. The hydrogen atom of the hydroxyl group can be replace by an active metal, such as sodium, potassium, and calcium, to form a metal methoxide (ethylate) with the evolution of hydrogen gas



- ✓ Sodium methoxide can be prepared by the reaction of absolute ethyl alcohol and sodium, or by refluxing absolute ethyl alcohol with anhydrous sodium hydroxide:



- ✓ Reaction with Hydrogen Halides:





Appearance	Colorless, clear liquid
Acidity	15.9
Boiling point	78.40C
Melting point	-114.3 ⁰ c
Specific gravity	0.79 to 20 ⁰ C
Density	0.798g/cm ³
Phase	Liquid
Molecular formula	C ₂ H ₅ OH
Surface tension	22.1Mm/m at 20 ⁰ C
Dipole moment	1.69D

Table 2. 2 Physical property of ethanol Chemical properties [17]

2.8 Feedstock for Bioethanol Production

Almost any plant- based material can be an ethanol feedstock. All plants contain sugars, and these sugars can be fermented to make ethanol in a process called biochemical conversion. Plant material also can be convert to ethanol using heat and chemicals in a process called thermochemical conversion. Some plants are easier to process into ethanol than others are. Some require few resources to grow, while others need intensive care. Some were used for food as well as fuel, while others are cultivated exclusively for ethanol; even plant-based wastes can become ethanol [16].

The following are different type's feedstock's for ethanol production.

Sugar: - Fermentation involves microorganisms that use the fermentable sugars for food and in the process produces ethanol and other byproducts. These microorganisms can typically use the 6carbon 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 [19]



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 baking. Other biomass feedstock 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.

2.9 Factor affecting Bioethanol production

There are some parameters affecting ethanol production process. These are temperature, pH, substrate concentration and yeast concentration as discussed below.

2.9.1 Temperature

Fermentation condition is an important parameter of fermentation process. Controlled condition can ensure maximum product from fermentation. Ethanol production is maximized by controlling fermentation temperature. Bio-ethanol production increases with the increase in temperature and reaches maximum value at 35°C. Further increasing temperature reduces the percentage of ethanol production and it is mainly due to denaturation of the yeast cells.

2.9.2. pH

If the pH of the substrate must be within acceptable limits of fermenter (enzymes), otherwise it will destroy the enzymes or reduce ethanol that can be fermented.

2.9.3. Substrate concentration

The amount of substrate to be fermented is proportional to the ethanol that can be fermented from it, if all other conditions are maintained.



CHAPTER THREE: MATERIALS AND METHODS

The experiment was carried out at Wolikite University in the Department of Chemical engineering laboratory. Centrifuge, Autoclave and Incubator used in the Department of Food processing engineering, oven and furnace used in the department of construction and technology management department and Characterizations of the product done in the Department of Chemistry at the College of Natural Science.

3.1. Materials

3.1.1. Equipment used

- ✓ Plastic bags: - to collect the samples and transport to the laboratory for processing.
- ✓ Ovens: - to dry the required sample.
- ✓ Mortar and Pestle: - to reduce the size/crush the dried sample.
- ✓ Sieves: - to sieve the grinded sample to the particle size of 1mm and 0.5mm
- ✓ Balances: - to weigh samples and chemical required.
- ✓ Digital pH meter: - to measure the pH of hydrolyzes before fermentation. .
- ✓ Centrifuge: - to separate the soluble liquid from non-soluble part.
- ✓ Graduated cylinders of different volumes: - for volume measurement.
- ✓ Fermentation and distillation set ups: - to ferment and distill respectively the samples.
- ✓ Water bath: - for sterilization and hydrolysis
- ✓ Furnace : - for characterization of raw material
- ✓ Filter paper:- for filtration process

3.1.2. Chemical apparatus used

- ✓ Test tube: - to hold sample and cultured bottle,
- ✓ Beaker (100ml or 200 ml):- to hold solution and shaker incubator.
- ✓ Mechanical stirrer: – to stir the solution and 4.1000– 200 ml conical flask
- ✓ Vessels: - to hold samples and additives for hydrolysis, fermentation and distillation Experiments

3.1.3. Chemicals and reagent

- 98% Sulfuric Acid (H_2SO_4): - used as a pretreatment and hydrolysis the coffee husk.
- Sodium Hydroxide (NaOH): - used to adjust the pH of soluble cellulose and hemicelluloses before fermentation.



- (Yeast extracts Agar): - used as media preparation.
- Urea: - used as media preparation.
- Dextrose sugar: - used as media preparation.
- *Saccharomyces cerevisiae*
- chromic acid

3.1.4. Raw material used

Coffee husk and water is the main raw material for production of bioethanol through fermentation.

3.2. Methods

3.2.1. Characterization of raw materials (coffee husk)

The proximate analysis method was used to characterize the sample coffee husk. Here moisture content (MC), volatile matter content, the fixed carbon content, the ash content (the inorganic residue remaining after combustion of the sample) of the sample coffee husk was evaluated.

3.2.1.1. Determine of moisture content (MC)

The moisture content of coffee husk is determined using an oven drier. The sample weighed to the Petri dishes and then dried at 83°C for 24 hours. The moisture content is determined using the following equation.

$$\begin{aligned} \text{MC (\%)} &= (W_1 - W_2 / W_1) * 100 = (1\text{kg} - 0.84\text{kg} / 1\text{kg}) * 100 \\ &= 16\% \end{aligned}$$

Where,

W_1 = initial weight of sample

W_2 = weight of sample after drying

3.2.1.2. Determination of volatile matter content (VM):

Volatile matter of the coffee husk is determined by heating the sample in the furnace in the absence of oxygen at 950°C for six minutes. The volatile matter computed as the difference between the initial weight and final weight the sample to the ratio of the weight of the sample.

$$\text{VM (\%)} = (W_1 - W_2 / W_1) * 100 = (1\text{kg} - 0.335\text{kg} / 1\text{kg}) * 100$$



$$= 66.5\%$$

3.2.1.3. Ash content (AC)

Ash content of coffee husk is determined by heating the coffee husk sample in a crucible at 750⁰C for three hours in the furnace. The ash content calculated as the proportion of the weight of the ash in the coffee husk to the weight of coffee husk sample as samples,

$$AC = (W_1 - W_2 / W_1) * 100 = (1\text{kg} - 0.978\text{kg} / 1\text{kg}) * 100 = 2.2\%$$

3.2.1.4. Fixed carbon content (FC)

The percentage of fixed carbon content of the coffee husk computed by subtracting the sum of volatile matter (VM), ash content (AC) and MC (moisture content) minus from 100.

$$\begin{aligned} FC (\%) &= 100 - (MC\% + VM\% + AC\%) = 100 - (16\% + 66.5\% + 2.2\%) \\ &= 100 - (84.7/100) = 0.153 * 100 \\ &= 15.3\% \end{aligned}$$

3.2.2 Experimental procedure

The study aimed at the production of ethanol and its characterization from coffee husk. Coffee husk were collect from Jimma region it collected in plastic bags and transported to the Chemical engineering laboratory for ethanol analysis. The following methods were followed, describes about the methodologies and approaches of how experiments were done in this research; it included all steps and procedures of the experiments.

The followings were basic steps for the production of ethanol, these processes were:

1. Collecting:- coffee husk was collect
2. Cleaning :- remove un wanted material by striping
3. Drying :- the coffee husks were dry in oven for 24 hr (83⁰C)
4. Grinding :- the dried coffee husk was grinded into two different size mesh (1mm,0.5mm) by using mortal and piston to get powder from husk of coffee
5. Pre-treatment :- powder husk contain lignin, hemicellulose and cellulose in kernel then in order to remove lignin, hemicellulose and crystal of cellulose we have to treated husk of coffee by using Sulphur dioxide and distil water
6. Acid hydrolysis :- after pre- treatment the cellulose convert to fermentable sugar by using dilute Sulphur dioxide (1%, 3% and 5%)
7. Fermentation : - a monomeric sugar which found after hydrolysis convert to ethanol with water by using media

8. Distillation :- it is our last process to find ethanol by separate water and ethanol using volatile difference

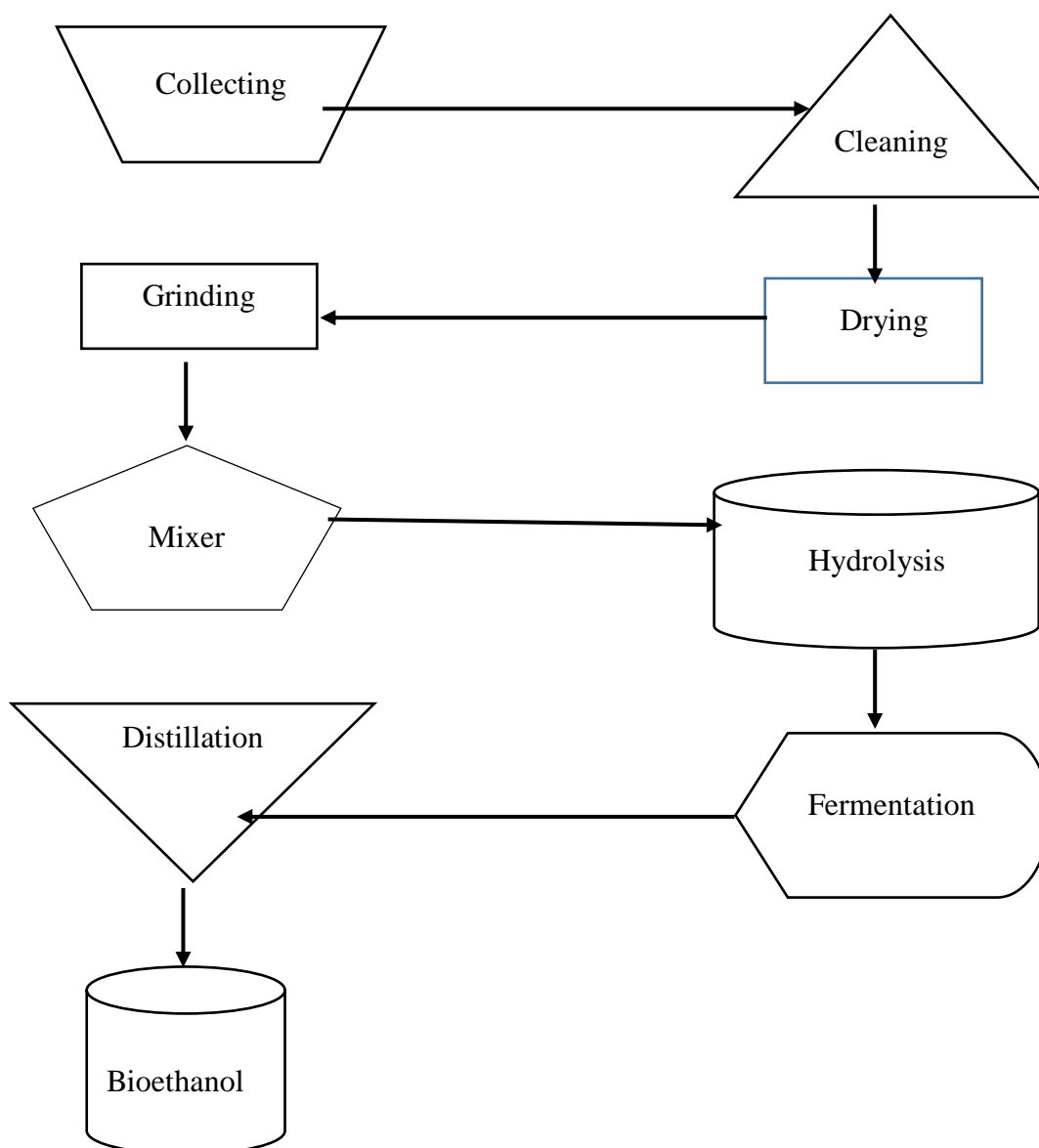


Figure 3. 1 flow diagram for bioethanol production from coffee husk

3.2.3. Sample preparation

3.2.3.1. Sample preparation

.The coffee husk collected from the area of Jimma town. Then the coffee husk dried in oven at 83⁰C for 24 hours. The dried coffee husk was size reduction (grinding) and sieving continued. Grinding of coffee husk powder from increased the surface area of the sample, which enhanced the contact between hemicellulose and cellulose with dilute acid to reduce cellulose crystallinity. The sample kept at room temperature until the next stage of temperature.



(a) Coffee plant

(b) coffee husk

(c) coffee husk powder

Figure 3. 2 coffee plant, coffee husk and coffee powder

3.2.3.2. Pre -treatment of coffee husk

Chemical pretreatment method by using dilute sulfuric acid (H_2SO_4) used to destroy hemicellulose, lignin shell, to protect cellulose and to decrease crystallinity of cellulose.

The pretreatment done by mechanical stirrer at 200 rpm for 24 hrs. In the laboratory. The amount of sulphuric acid used in the pretreatment step was 1% (v/v) ratio with distill water that means for 1ml of H_2SO_4 , it requires 99 ml of distill water. The amount of solid sample (powder coffee husk) can be determined based on the literature that we used as 1:5, i.e. for 5ml of solution it requires 1gram of sample coffee husk. Then we calculate the total amount of sulphuric acid and distil water needed for our sample.

Therefore, for pretreatment of 300 gram of sample coffee husk powder we have used;

- ✓ 15ml of H_2SO_4
- ✓ 1485ml of distill water

By mixing in flask with 200rpm of speed of stirrer for 24 hrs. It was set in the laboratory.

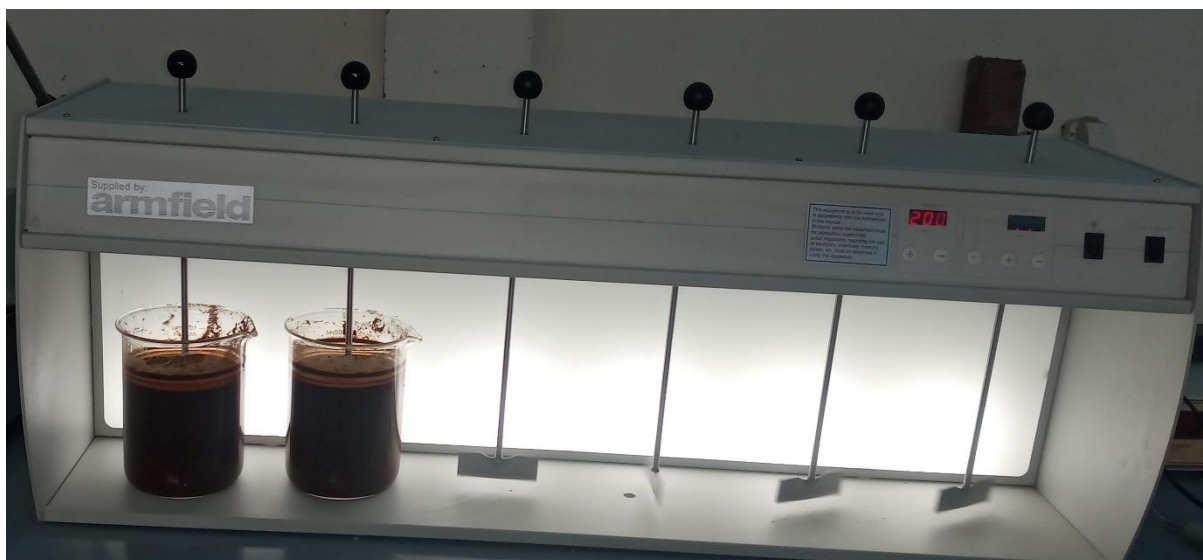


Figure 3. 3 pretreatment done by mechanical stirrer

3.2.3 3. Filtration

The sample from pretreatment was filtered using filter paper. The solution from this was acidic and further adjusted PH by adding NaOH solution and washing using distilled water until PH becomes 5-6. After that the solid part of the sample was dried in oven for 24hrs at 105 °C. Then the sample was stored in plastic bag at room temperature.



Figure 3.4 filtration process by using filter paper

3.2.3.4. Dilute Acid Hydrolysis

The weight of the solid part (cellulose) of the sample after pretreatment was decrease. This sample hydrolyzed with two factors and three levels. Literature works on the dilute acid hydrolysis of different lignocellulosic materials have defined optimal process conditions for size and dilute sulfuric acid. In this step the pretreated sample that means the cellulose part can be degraded or converted to glucose in the below procedures the following.



- ✓ 15.3ml of 3 % (v/v) diluted sulfuric acid was added to 100g of insoluble component from pretreatment steps and added 484.7ml distil water.
- ✓ The coffee husk was then hydrolyze in the reactor at 130⁰C for 50 min.
- ✓ After hydrolysis, neutralized with 10 M NaOH until the pH became around 5-6.
- ✓ Separate the solid particles from the liquid in the hydrolyzed sample by centrifugation (to remove the non-fermentable lignin portion).
- ✓ After separate the solid part, the solid part washed with distilled water for two times. The washing performed in order to extract all soluble sugars from the solid coffee husk material.
- ✓ The soluble component mixed with the previously filtered solution from the pretreatment step for the next procedure.

3.2.3.5. pH Adjustment

- ✓ wise to the other flask with constant stirring until the reaches to a range of 5.0-5.5
The pretreated and hydrolyzed solution were mixed, filtered, shaken substrate were checked for pH using a digital pH meter then we obtained pH of 5.0-5.5
- ✓ The mixed samples (pretreated and hydrolyzed) were acid hydrolyzed, so it needs highly basic solution to bring the in the range of 5.0-5.5.
- ✓ Sodium hydroxide solution was added drop.

3.2.3.6. Media preparation

Chemicals for media preparation for fermentations processes are.

For preparing 150ml media

- ✓ Sugar (dextrose sugar) =10gm
- ✓ Yeast extract =1gm
- ✓ Urea =0.5gm
- ✓ Make up water =150ml
- ✓ Yeast, *saccharomyces cerevisiae* =0.5gm

Procedures in Media Preparation

- ✓ To the above 150ml media, 0.5gm of yeast, *Saccharomyces cerevisiae* added in a 250 ml conical flask.
- ✓ The conical flasks properly covered with aluminum foil.
- ✓ The conical flask placed in a shaking incubator for 24 hours, at temperature of 30 and 200rpm.



Figure 3. 5 Media for fermentation

3.2.3.7. Fermentation

Fermentation of the hydrolyzed sugar continued to produce bio-ethanol. The sample and media mixed in the flasks with the ratio of 10:1 (1% media with 10% sample) based on the recommended data in the literatures. The volume of the sample was 1500ml and 150ml of media added based on the proportion above. After well mixing the sample and the media, it placed in water bath at a temperature of 30 °C for 72 hours to ferment the produced glucose to bioethanol.



Figure 3. 6 fermentation

3.2.3.8. Distillation

Distillation is the final step in the production of ethanol, its purification step. Distillation is a method used to separate two liquids based on their boiling point difference. However, to achieve high purification, several distillations are required. In this experiment, separation used by simple distillation at a temperature of 78⁰c for 3hrs.



Figure 3.7 distillation process

Components of experimental setup for simple distillation

- ✓ Heating mantel
- ✓ Condenser
- ✓ Diverting glass that fits at the end of condenser.
- ✓ Harvesting vessel (flask).
- ✓ Round-bottom flask.
- ✓ Distilling adapter



CHAPTER FOUR: RESULT AND DISCUSSION

The process consists of four parts: pretreatment to remove lignin, reduce cellulose crystalline, sterilize the coffee husk and increase the porosity of materials, dilute acid hydrolysis, fermentation to produce ethanol and distillation to separate ethanol from water. After the following above series procedures, the experiment outcomes of these particular results measured to know the yield of ethanol concentration. There were six experiments conducting by varying of sample and diluted sulfuric acid concentration. The amount of product obtained for each sample measured.

Sample	Size of sample(mm)	%(v/v)Dilute sulfuric acid	Amount of bio ethanol obtained
Sample one	0.5	1	28.45
Sample two	0.5	3	34.2659
Sample three	0.5	5	26.764
Sample four	1	1	26.071
Sample five	1	3	24.282
Sample six	1	5	22.34

Table 4. 1 size of sample and amount of product

4.1. Yield analysis

The procedure for the production of bioethanol from cellulose by SHF discussed in chapter 3; here 100g of coffee husk powder is used to produce ethanol by acid hydrolysis using H_2SO_4 as the acid. Theoretically, 50.18.g of sugar can be produce from 100g of coffee husk. The yields obtained by different size of coffee husk and dilute acid hydrolysis can be calculate as follow:

$$\begin{aligned}\% \text{ Yield} &= \text{amount of bioethanol}/\text{amount of sugar convert to alcohol} * 100 \% \\ &= 56.6\%\end{aligned}$$



samples	Size of sample(mm)	%(v/v)H ₂ SO ₄ added	Amount of bioethanol obtained(gm)	% yield
Sample one	0.5	1	28.45	56.6
Sample two	0.5	3	34.2659	68.28
Sample three	0.5	5	26.764	53.3
Sample four	1	1	24.282	48.3
Sample five	1	3	26.011	51.8
Sample six	1	5	22.34	44.5

Table 4.2 size of sample and yield of bioethanol

❖ Yield analysis by size of sample and sulfuric acid concentration

The size of the samples has great effect on bioethanol production. If size of samples increases the amount of ethanol, production decreases. This due to that some portion of cellulosic portion is not changed to sugar or glucose.

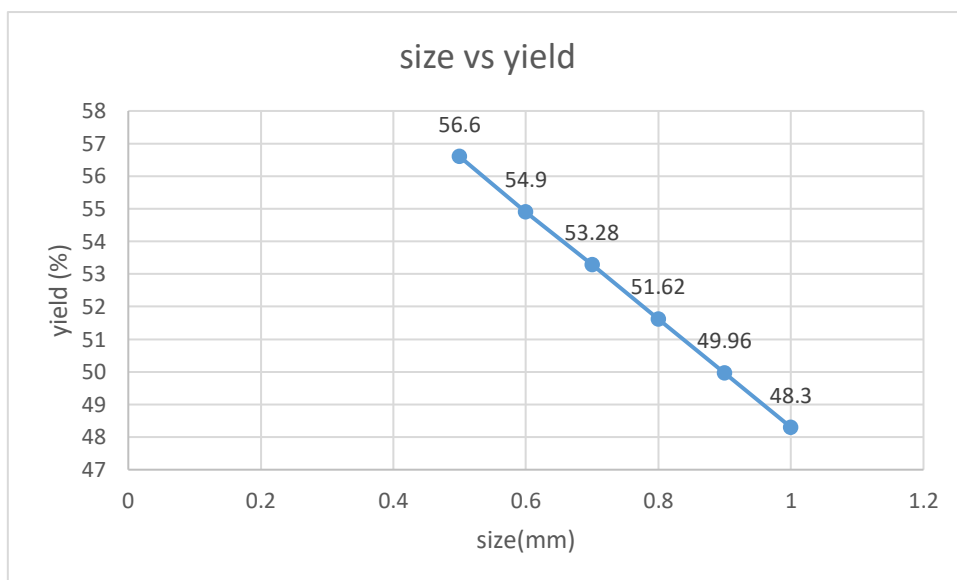


Figure 4.1 size vs yield for 1% (v/v) H₂SO₄

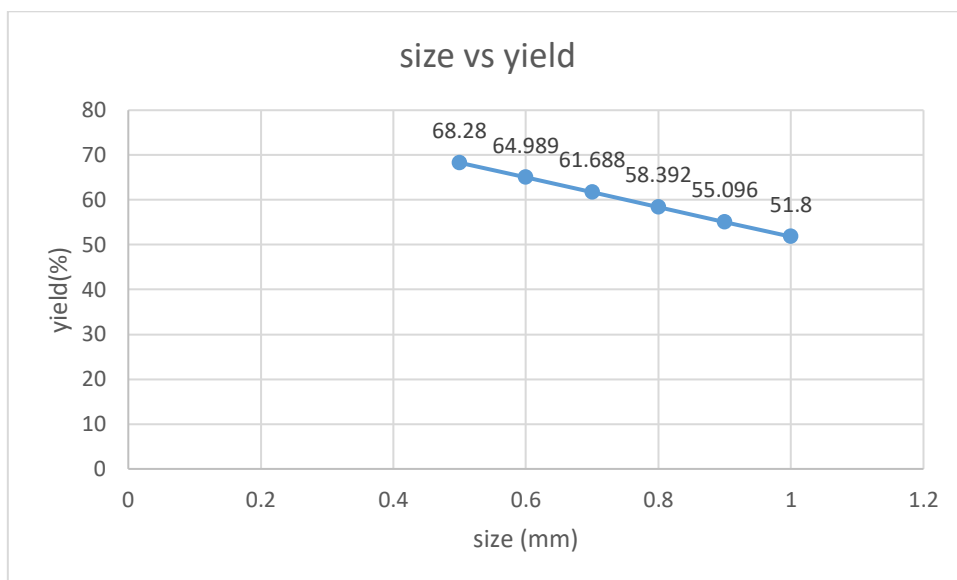


Figure 4. 2 size vs yield for 3% (v/v) H₂SO₄

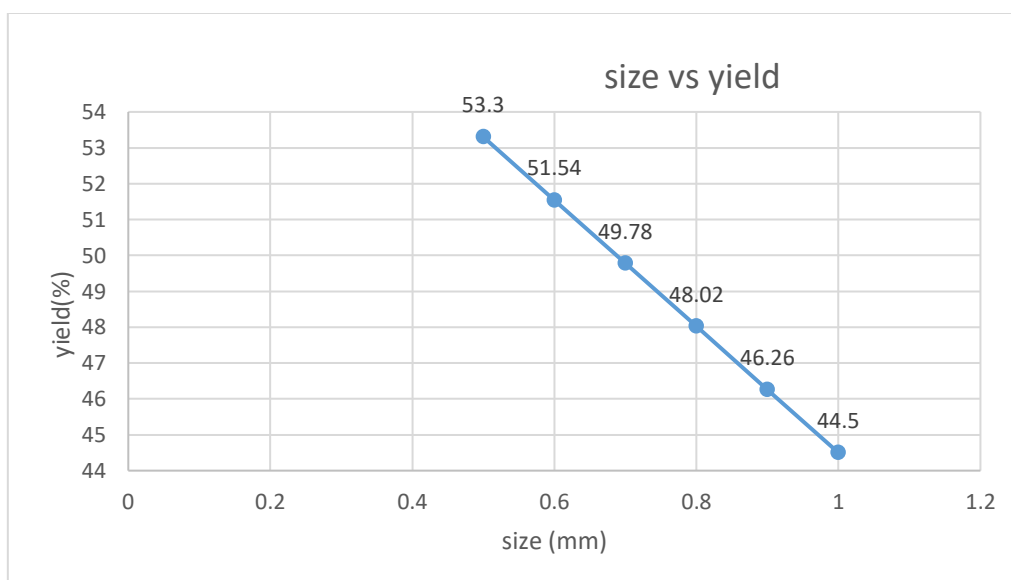


Figure 4.3 size vs yield for 3% (v/v) H₂SO₄

The above figure briefly indicates that for increasing of sample size the yield be decreasing.

Diluted sulfuric acid: Diluted sulfuric acid concentration has less effect on the bio-ethanol production from coffee husk with relative to the size of the sample. Since the concentration of diluted acid increases, the sugar content in the coffee husk decreases. This result in the decrease of bio-ethanol yield. As illustrated for 1 % (v/v) H₂SO₄, the yield of sample one (S1) is 56.6%, for 3% (v/v) H₂SO₄ the yield of sample two (s2) is 68.28% and



the yield of 5 % (v/v) H_2SO_4 used for same size of sample three (s3) is 26.282%. Thus, the increasing of diluted sulfuric acid concentration directly affects the yield of bio-ethanol.

Since the concentration of diluted acid increases, the sugar content in the coffee husk decreases.

4.2. Characterization of product

Characterization of laboratory product (bioethanol) is important to determine whether the product, which obtained is similar or different in physical or chemical properties of these, which were already produced in commercially.

4.2.1 Characterization by pH

The PH value is the one criterion to distinguish if the product is in its range or out of the range.

The optimum value PH of commercial ethanol from 5 to 5.5.

Sample	Size of sample(mm)	%(v/v) H_2SO_4	PH
Sample one	0.5	1	7.2
Sample two	0.5	3	5.3
Sample three	0.5	5	5.1
Sample four	1	1	5.4
Sample five	1	3	6.8
Sample six	1	5	4.3

Table 4. 3 PH value for each sample

PH value of sample (S_6) deviates from the range, hence it is in acidic media. PH value of the sample (S_2 , S_3 and S_4) are in range value. So that these three samples are optimized. PH of samples (S_1 and S_5) is in basic media. Therefore, samples not optimized.



4.2.2 Characterization of bioethanol by using physical properties

When we characterize our ethanol, we observe that it is clear, colorless liquid, and volatile under ordinary condition

4.2.3. Characterization of bioethanol by using chemical

We characterize our ethanol by using chromic acid, when we mix our ethanol with chromic acid it oxidized and change the color of chromic acid from orange red to green



CHAPTER FIVE: MATERIAL AND ENERGY BALANCE

Material and energy balances are very important in an industry. Material balances are fundamental to the control of processing, particularly in the control of yields of the products. The increasing cost of energy has caused the industries to examine means of reducing energy consumption in processing. The basic principle for both material and energy balance simply based on the following equation:

$$\text{Input} - \text{Output} + \text{Generation} - \text{Consumption} = \text{Accumulation}$$

Assumption,

There is no generation, accumulation (steady state operation), consumption.

5.1 Material Balance

In all the mass balance calculations, no mass accumulation in the design process assumed. Since the mass balance involved reaction, it calculated by using the mole flow of each compound when reaction is involved in the process. Each reaction depends on the conversion of reaction since all the reactions assumed in equilibrium and the number of moles consumed in the reaction is equal to the number of generate in the process. In mole basis, the relation becomes:

$$\sum (F_i) \text{ input} + \sum (F_i) \text{ generated} = \sum (F_i) \text{ output} + \sum (F_i) \text{ consumed}$$
 Basic data

Basic data

- ✓ Taking 24 hr of work per day
- ✓ Density of ethanol 790 kg/m³
- ✓ Working days per year =300
- ✓ Capacity of the plant=5*10⁶lit/yr. of ethanol (99.5%)

$$\begin{aligned} \text{Anhydrous ethanol (lit/hr.)} &= (\text{Total capacity}) / (\text{operation time}) \\ &= (5,000,000/\text{year}) / (24\text{hr}/\text{day} * 300\text{day}) \\ &= 694.44 \text{ l/hr.} \end{aligned}$$

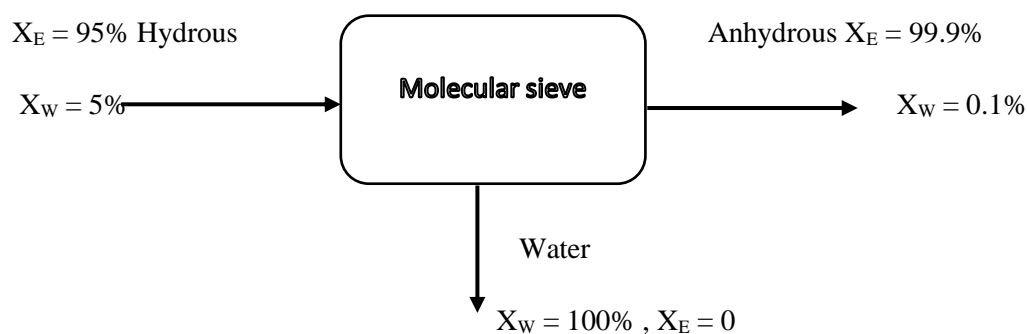
$m = \rho \times v$ where ρ = density of ethanol

$$\begin{aligned} m &= 790\text{kg}/\text{m}^3 \times 694.44 \text{ l/hr} \\ &= 548,611.1\text{kg}/\text{hr.} \end{aligned}$$



5.1.1. Material balance on molecular sieve

The equipment molecular sieve gives ethanol concentration of 95% to 99.5%. If the commercial ethanol concentration lies b/n range 95% to 99.5%



Where

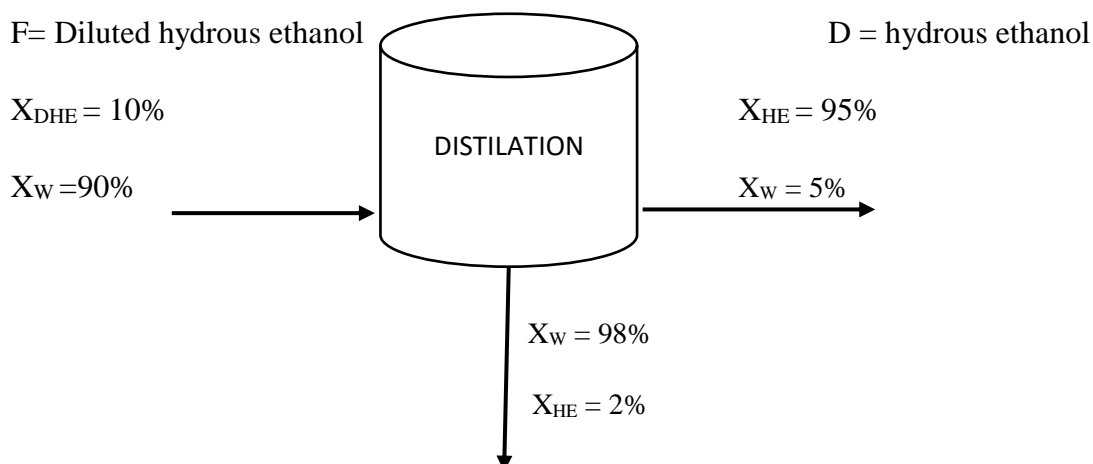
X_E = percent of ethanol

X_W = percent of water

$$\begin{aligned} \text{❖ Hydrous ethanol in} &= \text{anhydrous ethanol} / (1 - \text{percentage of hydrous ethanol fraction}) \\ \text{To sieve} &= 694.44 \text{ l/hr} / (1 - 0.05) = 730 \text{ l/hr} \end{aligned}$$

Material balance on distillation

It is the equipment used for purification of ethanol from water-ethanol mixture. The mixture from fermentation enter into the distillation with the mixture of 10% ethanol and the rest water then with two series distillation column the purification of ethanol come to 95%.





From ethanol component balance

Where: X_{DHE} =diluted hydrous ethanol

H_E = hydrous ethanol

W =water

X_{DHE} = composition of diluted hydrous ethanol

X_W =composition of water

X_{HE} =composition of hydrous of ethanol

Total mass balance on distillation column

$$M_{DHE}=M_W+M_{HE} \text{ -----(5.1)}$$

Component balance

$$(M_{DHE})*(X_{DHE}) = (M_W)*(X_W) + (M_{HE})*(X_{HE}) \text{ ----- (5.2)}$$

From equation (5.1)

$$M_W=M_{DHE}-694.4\text{Kg/hr.}$$

$$(M_{DHE})*(X_{DHE}) = (M_W)*(X_W) + (M_{HE})*(X_{HE})$$

$$M_{DHE}= (M_W X_W+M_{HE} X_{HE})/X_{DHE}$$

$$\begin{aligned} M_{DHE} &= M_W(0.02) +694.4(0.95)/0.1 \\ &= 0.2M_W + 6596.8 \end{aligned}$$

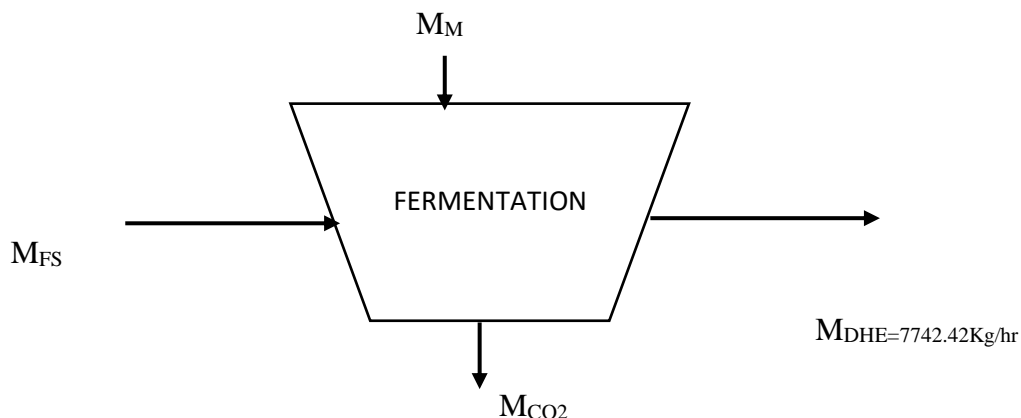
Where

$$M_{DHE} = M_W + 694.4 = 0.2M_W + 6596.8=M_W+694.4$$

$$M_W =5728.08\text{Kg/hr.} \quad M_{DHE}= 7742.42 \text{ Kg/hr.}$$

5.1.2. Material balance on fermentation

For fermentation process input materials are:



Where,

M_{FS} = mass flow rate of filtered solution from centrifuge

M_M = mass flow rate of media solution

M_{CO_2} = mass of CO_2 released from fermentation

From anaerobic reaction of fermentation



Media

For 100% conversion:



But, 1 to 3% of glucose cannot be changed to ethanol

The accurate efficiency of glucose conversion is 97%

Mass of glucose feed for fermentation is the same as mass of filtered solution from centrifuge.

$$\text{Thus } M_{GF} / 180 \text{ g/mole} = 7742.42 \text{ Kg/hr} * 0.97 / 92 \text{ g/mole}$$

$$M_{GF} = 14693.7 \text{ kg/hr}$$

The amount of CO_2 released as by product is:

$$M_{GF} / (180 \text{ g/hr.}) = M_{CO_2} / (88 \text{ g/hr.}) \quad M_{CO_2} = 7183.6 \text{ kg/hr.}$$



The amount CO₂ produced in fermentation is 7183.6kg/hr.

From total mass balance:

$$\sum \text{Input} = \sum \text{Output}$$

$$M_{FS} + M_M = M_{DHE} + M_{CO_2} \quad \text{-----(5.4)}$$

Mass of media is 10% of the mass of filter, hence from Eqn. (5.4)

$$M_{FS} + 0.1M_{FS} = M_{DHE} + M_{CO_2}$$

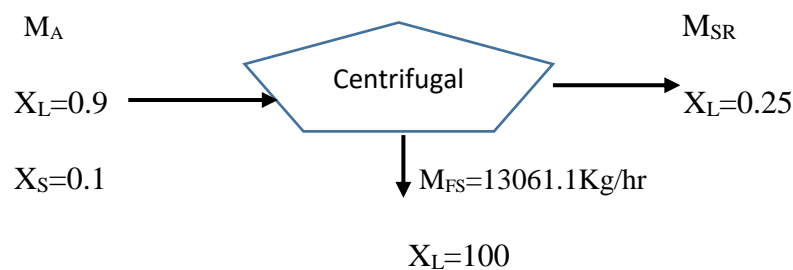
$$1.1M_{FS} = M_{DHE} + M_{CO_2} = 7742.42 \text{kg/hr} + 7183.6 \text{kg/hr}$$

M_{FS} = 13061.1kg/hr. of filtered solution from centrifuge is entered into the fermentation stage.

$$\text{Mass of media} = 7742.42 + 7183.6 - 13061, \quad M_m = 1864.92 \text{Kg/hr}$$

5.1.3. Material balance on centrifugation

Centrifugation is nothing but it used to separate solid from liquid Moisture content of centrifuge solid is 25%.



Where

M_A = mass flow rate of acid treated fluid

M_{FS} = mass flow rate of filtered solution

M_{SR} = mass flow rate of solid residue

X_L = fraction of liquid, X_S = fraction of solid component

Total material balance:

$$M_A = M_{SR} + M_{FS}$$

From the solid component balance

$$M_A X_S = M_{SR} X_S + M_{FS}$$

$$M_A = 10M_{SR}X_S \quad \text{-----} \quad (5.5)$$

From liquid component balance

$$M_A X_L = M_{SR} X_L + M_{FS} X_L$$

$$0.9M_A = M_{SR} (0.25) + M_{FS} (1) \quad 0.9M_A = 0.25M_{SR} + 13061.1 \text{ kg/hr.}$$

$$M_A = 0.28M_{SR} + 14512.3 \text{ Kg/hr} \quad \text{-----} \quad (5.6)$$

Equate Equation (5.5) & (5.6)

$$10M_{SR} (0.75) = 0.278M_{SR} + 13061.1 \text{ Kg/hr}$$

$$7.5M_{SR} = 0.25M_{SR} + 13061.1 \quad 7.25M_{SR} = 13061.1 \quad M_{SR} = 1801.5 \text{ kg/hr.}$$

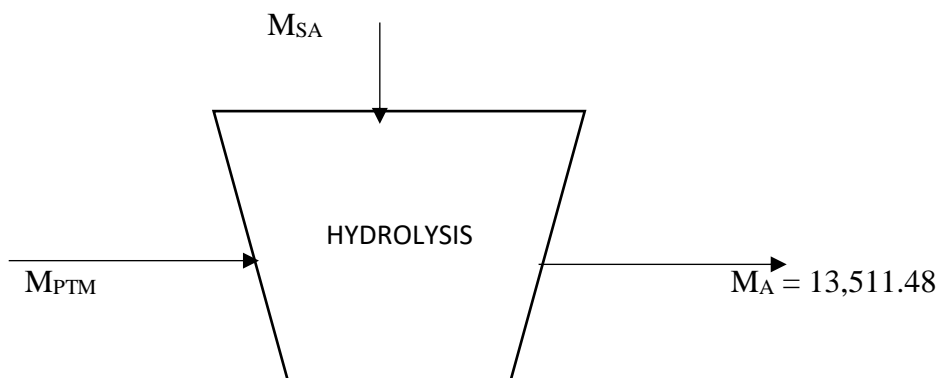
Mass flow rate of acid treated solution is

From equation (5.5)

$$M_A = 10M_{SR}X_S = 10 * (1801.5 \text{ kg/hr.}) * 0.75 \quad M_A = 14998.7 \text{ kg/hr.}$$

5.1.4. Mass Balance for Diluted Acid Treatment (Hydrolysis)

The pretreated sample is soaked with 1% sulfuric acid to convert cellulose to glucose and serve as catalyst, meaning it has no reaction with cellulose. Material balance on hydrolysis



M_{PTM} = Mass flow rate pretreated mixture, M_{SA} = mass of diluted sulfuric acid

Reaction takes place in hydrolysis is Cellulose reacts with water as presence of diluted sulfuric acid give glucose.



Assume 96% of cellulose converted to glucose

$$M_{PTM}/M_{CELL} = M_A/M_{GLUCOS}$$



$$M_{PTM} = (13511.48)/180 * (M_{PTM} = 13498.83 \text{Kg/hr.}$$

From total mass balance

$$M_{PTM} + M_{SA} = M_A \quad M_{SA} = M_A - M_{PTM} = (14998.7 - 13498.83) \text{ kg/hr.}$$

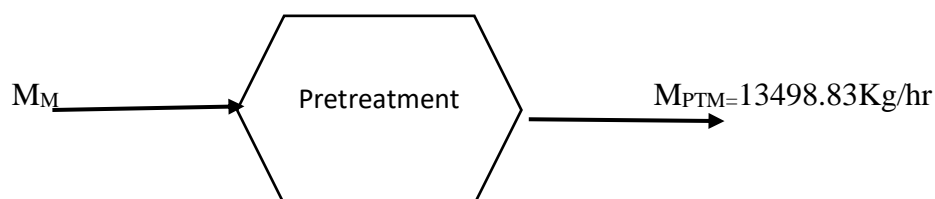
$$= 1499.87 \text{kg/hr. Of 3\% dilute sulfuric acid}$$

From component mass balance of sulfuric acid:

$$\text{Mass of sulphuric acid} = 3\% * 1499. = 44.996 \text{Kg/hr. H}_2\text{SO}_4$$

$$\text{Mass of distilled water} = 97\% * 1499.87 \text{Kg/hr.} = 1454.87 \text{Kg/hr.}$$

5.1.5. Material Balance on Pretreatment



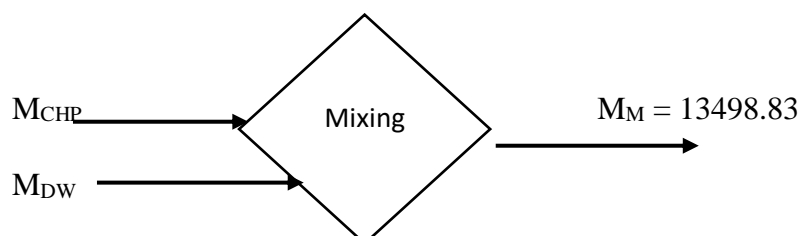
$$M_M = M_{PTM} = 13498.83 \text{kg/hr}$$

5.1.6. Mass Balance for Mixing

Input for mixing is:

Dry coffee husk powder

➤ Distilled water





Where,

M_{CHP} = mass flow rate of dry coffee husk powder , M_{DH} =mass flow rate of distilled water

$$\sum M_{in} = \sum M_{out}$$

$$M_{CHP} + M_{DW} = M_M \quad \text{-----} \quad (5.7)$$

The amount of coffee husk powder mixed with distilled water is 1:10 respectively.

$$M_{CHP}/M_{DW} = 1/5$$

$$M_{CHP} = 0.2M_D \quad \text{-----} \quad (5.8)$$

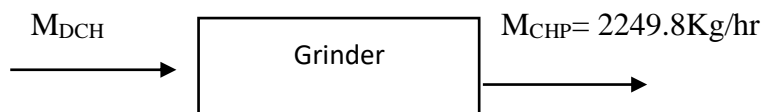
Substitute Equation. (5.8) in Eqn. (5.7)

$$0.2M_{DW} + M_{DW} = M_M \quad 1.2M_{DW} = 13498.83 \text{kg/hr.}$$

$M_{DW} = 11249.03 \text{kg/hr.}$ of distilled water is used To find mass dry coffee husk powder, substitute it in equation. (5.8)

$$M_{CHP} = 0.2 * M_{DW} = 0.2 * 11249.03 \text{kg/hr.} \quad M_{CHP} = 2249.8 \text{ Kg/hr}$$

5.1.7. Material balance on grinder



The moisture content of coffee husk leave the dryer is 0% (i.e. 100% dried).The grinder is used to reduce the size of sample. 90% of coffee husk is converted to coffee husk powder, and 10% of coffee husk is spent during grinding.

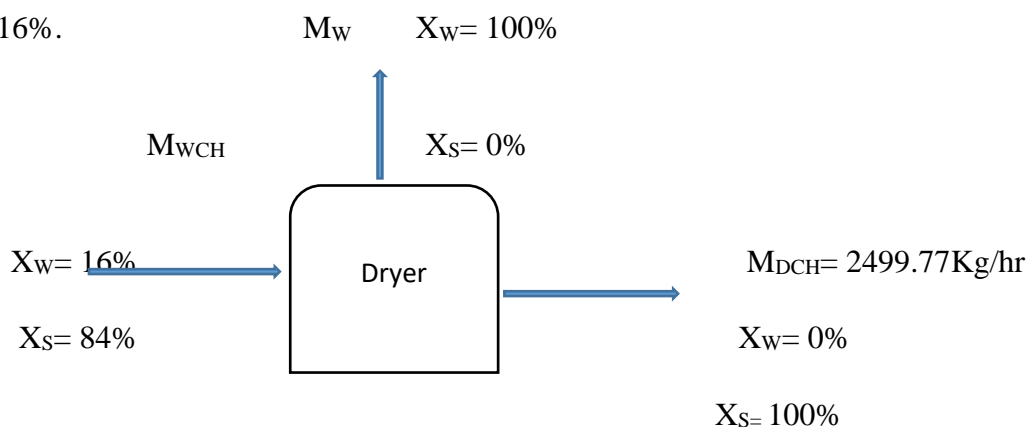


Where, M_{CHP} = mass flow rate of coffee husk powder $M_{CHP} = 90\%M_{DCH}$

$$M_{DCH} = M_{CHP}/90\% = 2249.8\text{kg/hr.}/0.9 = 2499.77\text{Kg/hr.}$$

5.1.8. Material Balance for Dryer

Dryer is used to wet dry coffee husk. From calculated moisture content of wet coffee husk is 16%.



Where

M_{CHP} = mass flow rate of wet coffee husk

X_W = fraction of water in coffee husk , X_S = fraction of solid in coffee husk

Over all mass balance

$$M_{WCH} = M_W + M_{DCH} \quad M_W = M_{WCH} - M_{DCH}$$

$$M_W = M_{WCH} - 2499.77 \quad \text{----- (5.9)}$$

Component mass balance of solid for dryer

$$M_{WCH} * X_S = M_W * X_S + M_{DCH} * X_S$$

$$0.84M_{WCH} = (M_W * 0) + (M_{DCH} * 1) \quad 0.84M_{WCH} = M_{DCH}$$

$$M_{WCH} = M_{DCH}/0.84 = (2499.77\text{kg/hr.})/0.84 = 2975.91\text{kg/hr.}$$

From Eqn. (5.9)

$$M_W = M_{WCH} - 2499.77 = (2975.91 - 2499.77) \text{ kg/hr.}$$

$M_W = 476.14\text{kg/hr.}$ of water removed from wet coffee husk

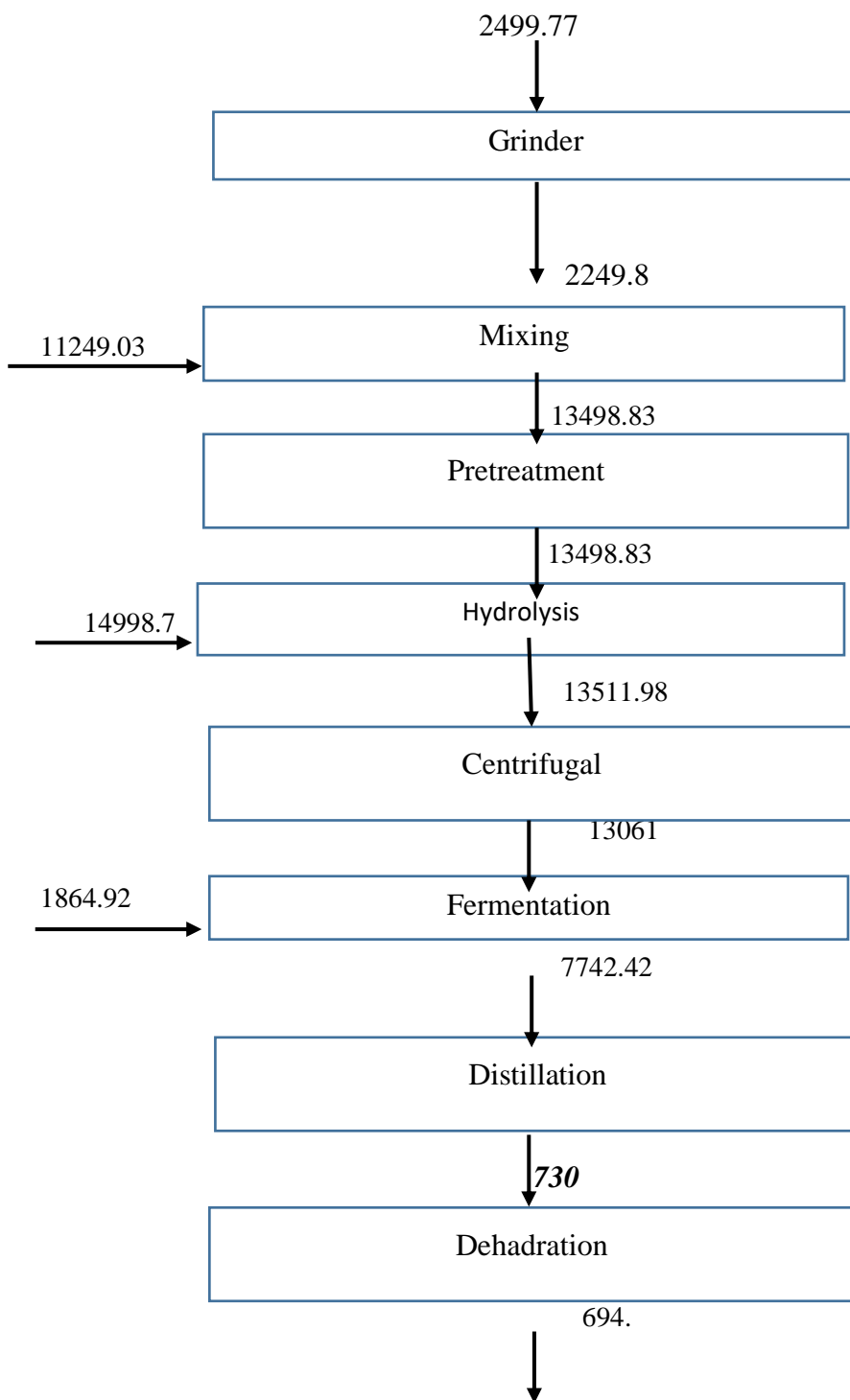


Figure 5. 1 summarizations of material balance

5.2. Energy balance

In process design, the energy balance made to determine the energy requirement of the process: The heating, cooling, and power required.in plant operation an energy balance (energy audit) on the plant will show the pattern of energy usage and suggest areas for conservation and savings. As with mass, energy can be consider to be separately conserved

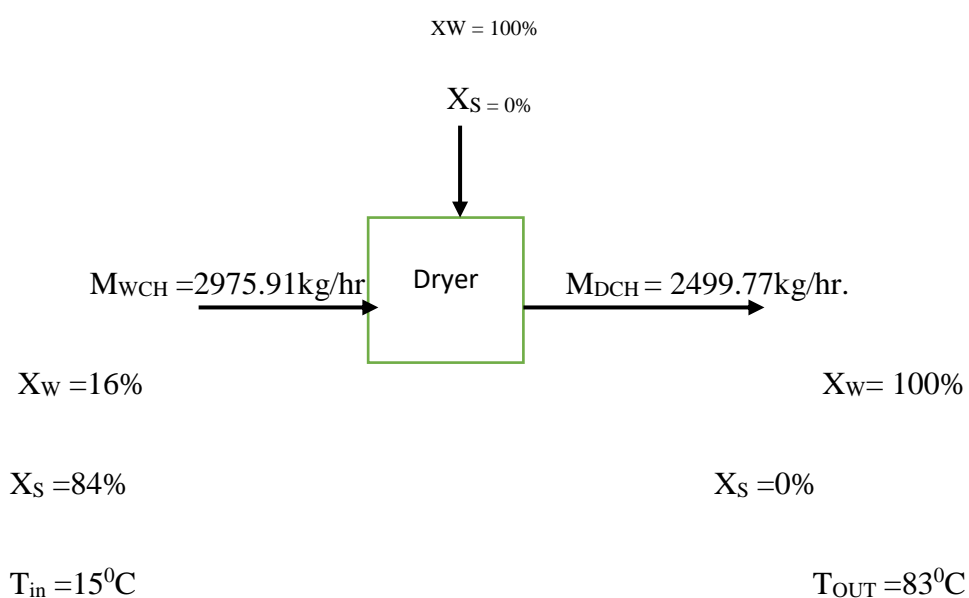


in nuclear processes. The conservation of energy, however, differs from that of mass in that energy can be generate (or consumed) in a chemical process.

	Ethanol	Water
Specific gravity (kj/kg.k)	3.9	4.18
Density (kg/m ³)	790	1000

5.2.1. Energy Balance on Dryer

$$M_W = 476.14 \text{ kg/hr.}$$



The collected coffee husk then dried in oven at 83°C for 24hr. The initial temperature of the drier is 15°C The sample is dried by temperature b/n 15°C and 60°C

The energy required is:

$$Q = mC_P\Delta T$$

Where = mass flow rate of wet coffee husk.

C_P = Specific heat capacity of wet coffee husk.

ΔT = Temperature gradient

From material balance mass of wet coffee husk (M_{WCH}) is:



$M_{WCH}=2975.91\text{kg/hr. } ^\circ\text{k}$, $\Delta T=T_{in} - T_{out} = 83^\circ\text{C}-15^\circ\text{C} = 68^\circ\text{C}$ Specific heat capacity of wet coffee husk is:

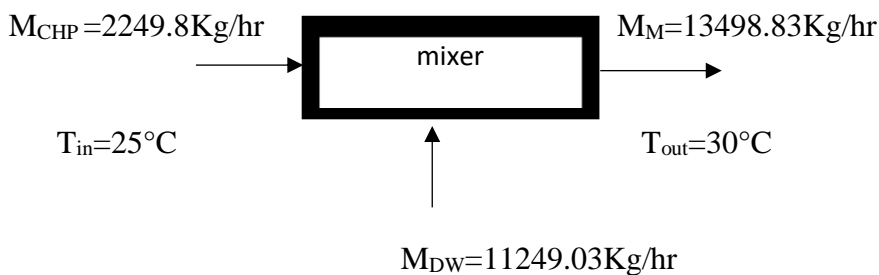
$$C_p=C_pWCH*XS+C_pW*X_w$$

$$=3.9*0.84+4.18*0. =3.9448 \text{ kJ/kg. } ^\circ\text{k}$$

$$Q =mC_p\Delta T=2975.91\text{kg/hr. } *3.9448\text{kJ/kg. } ^\circ\text{k} * (68^\circ\text{k})$$

$$=798,277.14\text{kJ/hr.}$$

5.2.2. Energy balance on mixer



The energy used to mix the coffee husk powder and distilled water

Where,

M_{DCHP} = mass flow rate fee husk powder

M_M =mass flow rate mixture of dried coffee husk

M_{DW} =mass flow rate of distilled water

Specific heat capacity of coffee husk powder (C_{pCH})

$$C_{PCH} = M_M * C_{PC} + M_{DW} * C_{PW} / M_M + M_{DW}$$

$$[(13498.83*3.9) +(11249.03*4.18)] / (13498.83+11249.03) = 192.128\text{kJ/kg}^0\text{k}$$

The heat required for mixing is:

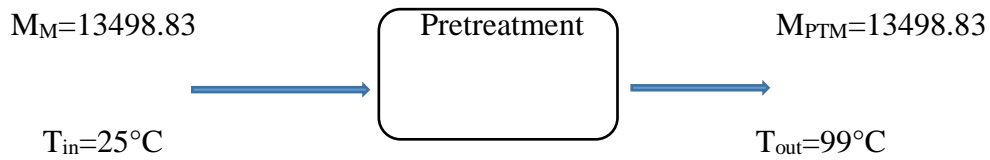
$$Q = M_m * C_p \Delta T$$



$$\Delta T = T_{out} - T_{in} = 30^{\circ}\text{C} - 25^{\circ}\text{C} = 5^{\circ}\text{C}$$

$$Q = 13498.83 \text{ kg/hr} \cdot 4.15 \text{ kJ/kg} \cdot 5 \text{ K} = 280100.55 \text{ kJ/hr}$$

5.2.3. Energy Balance on Pretreatment



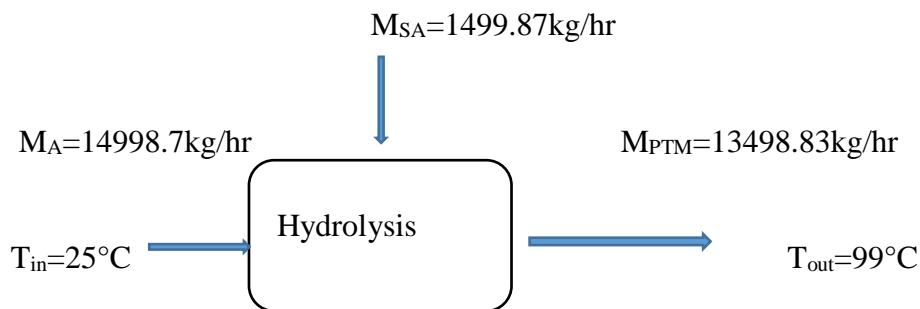
The pretreatment process done within the temperature of autoclave from 25°C to 99°C. $Q = MC_P\Delta T$

$$C_p = C_{pCH} = 4.15$$

$$Q = MC_P\Delta T = 13498.83 \text{ kg/hr} \cdot 74 \text{ K} \cdot 4.15 \text{ kJ/kg} \cdot \text{K} = 4145,235.8 \text{ kJ/hr}$$

5.2.4. Energy Balance for Hydrolysis

Energy is used to hydrolysis to cellulose to glucose



The specific heat capacity of pretreated mixture is:

$$C_{PM} = \frac{M_{PTM} C_p + M_{SA} C_{pW}}{M_{PTM} + M_{SA}}$$

$$= \frac{[(13498.83 \cdot 3.9) + (1499.87 \cdot 4.18)]}{(1499.87 + 13498.83)}$$

$$C_{PM} = 3.93 \text{ kJ/kg} \cdot \text{K}$$

The heat required for hydrolysis is:

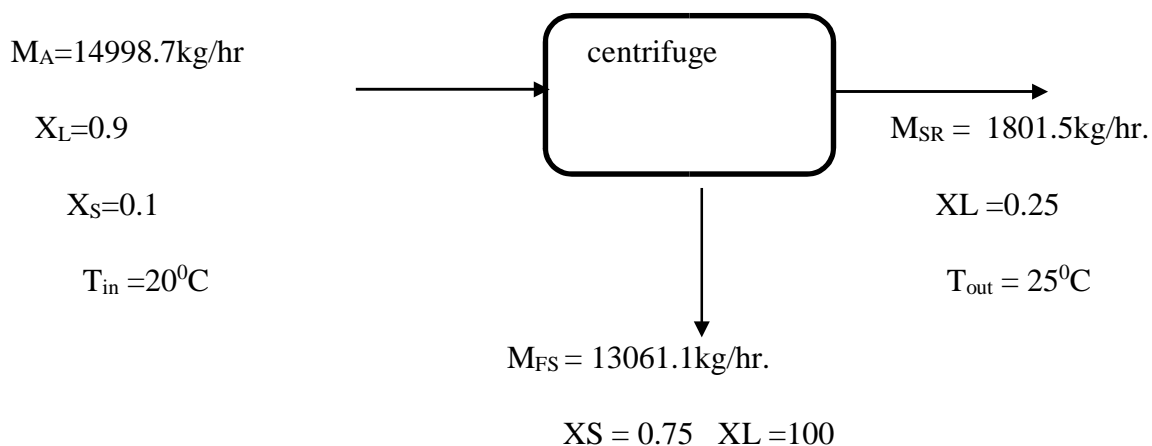


$$Q = M_A C_p \Delta T$$

$$= 14998.7 \text{ kg/hr.} * 3.93 \text{ kJ/kg.k} * 74 \text{ K} = 4,361,718.36 \text{ kJ/hr.}$$

5.2.5. Energy Balance on Centrifuge

Centrifuge is used to separate clear liquid solution from insoluble part.



The heat capacity of hydrolyzed sample is.

$$C_{PS} = (M_{SR} * X_S * C_{pW_{CH}} + M_{SR} * X_L * C_{pW}) / M_{SR}$$

$$= (1801.5 * 0.75 * 3.94 + 1801.5 * 0.25 * 4.18) / 1801.5$$

$$= 4.0 \text{ kJ/kg.k}$$

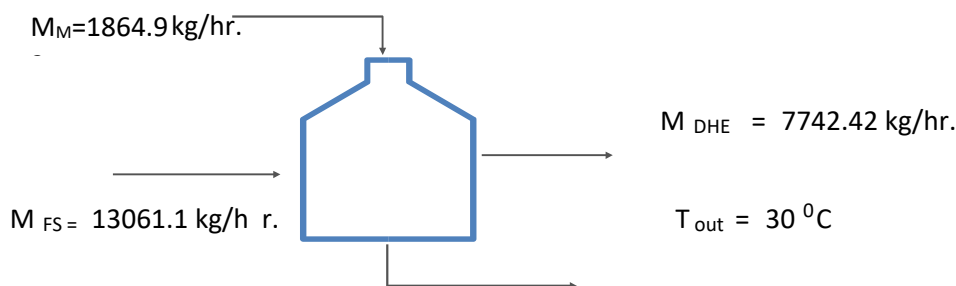
The heat released during the separation of solid portion can be calculated as

$$Q = M_{SR} C_p \Delta T + M_{FS} C_p \Delta T$$

$$= 1801.5 * 4.0 * 5 \text{ K} + 13061.1 * 4.18 * 5 \text{ K}$$

$$= 309,006.99 \text{ kJ/hr}$$

5.2.6. Energy Balance on Fermentation



$$T_{in} = 25^{\circ}\text{C}$$

$$M_{CO_2} = 7183.6 \text{ kg/hr.}$$

$$Q_{system} = Q_{in} + Q_{gen} - Q_{out}, \quad Q_m = Q_{FS} + Q_M$$

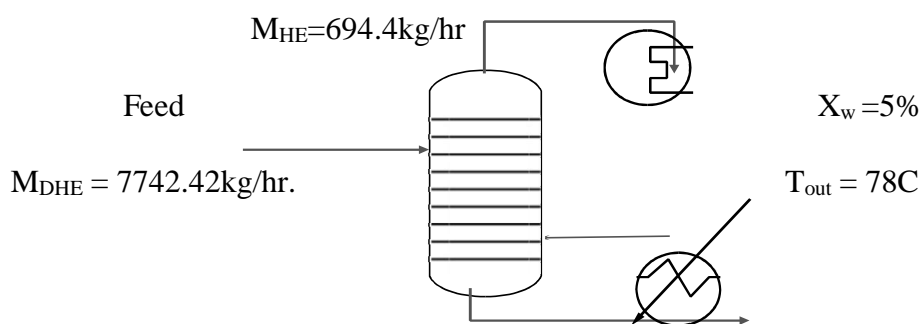
$$Q_M = Y_{\text{east preparation}} = 0, \quad Q_{gen} = 0 \text{ at steady state}$$

Q_{out} = heat required for diluted hydrolysis ethanol

$$C_p = 4.09 \text{ kJ/kg}$$

$$D_{\text{diluted ethanol}} = M C_p \Delta T = 1864.92 \text{ kg/hr.} * 4.09 \text{ kJ/kg.} * 5 \text{ k} = 38137.61 \text{ kJ}$$

5.2.7. Energy Balance on Distillation



Over all material balance

$$F = D + B \dots \dots \dots (5.10)$$

Component balance

$$F X_F = B X_B + D$$



$$7742.42 \cdot 0.1 = D \cdot 0.95 + B \cdot 0$$

$$774.242 = 0.95D, \quad D = 814.9 \text{ kg/hr.}$$

Mass flow rate of top product $694.4 = \text{kg/hr.}$

From equation. (5.10)

$$F = D + B, \quad B = F - D = (7742.42 - 814.9) \text{ kg/hr.}, = 6927.5 \text{ kg/hr.}$$

Energy balance

Basis:

- The initial temperature is 25°C
- The operation time is one hour.
- Specific heat capacity of distillate is:

C_p , distillate = 95% ethanol 5% C_p of H_2O

$$= 0.95 \cdot 3.9 + 0.05 \cdot 4.18 = 3.92 \text{ kJ/kg}\cdot\text{k} \quad \text{Heat capacity on bottom product}$$

Neglect heat loss

Heat capacity data Ethanol at 35°C , $C_p = 2.8 \text{ kJ/kg}\cdot^{\circ}\text{C}$ Water at

85°C , $C_p = 4.2 \text{ kJ/kg}\cdot^{\circ}\text{C}$

At feed: 10% ethanol, 90% water $C_p = (0.1 \cdot 2.8) + (0.9 \cdot 4.2) = 4.06 \text{ kJ/kg}\cdot^{\circ}\text{C}$

At top product side:

95% ethanol, 5% water $C_p = 0.95 \cdot 2.8 + (0.05 \cdot 4.2) = 2.87 \text{ kJ/kg}\cdot\text{k}$ at bottom side: 98% water removed, $C_p = 4.2 \text{ kJ/kg}\cdot\text{k}$

At steady state, Enthalpy of vapor = latent heat + sensible heat $H_v = V$ (latent + sensible heat)

5.2.8. Balance on condenser

Reflux ratio = 2.5

$$R = L/D = 2.5, \quad L = 2.5 \cdot D = 2.5 \cdot 814.9, \quad L = 2037.25 \text{ kg/hr.}$$

$$V = L + D = 2037.25 + 814.9 = 2852.15 \text{ kg/hr.}$$

$$H_v = 2852.15 \{ (0.95 \cdot 6927.5 + 0.05 \cdot 2037.25) + 2.8 \cdot (53) \} = 19,062,009.8 \text{ kJ/hr.}$$



CHAPTER SIX: COST ESTIMATION AND ECONOMIC EVALUATION

Before attempts the design of a process and plant it is the responsibility of chemical engineer to make economic evaluation. It is essential that the chemical engineer be aware of the many different types of costs involved in the manufacturing process. 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 and financially feasible. The ultimate purpose for developing such a detailed process design and cost estimate is to determine the economics of ethanol production.

6.1 Total Capital Investment

The sum of the fixed capital investment and the working capital is known as the total capital investment. $\text{Total capital investment} = \text{Fixed capital investment} + \text{Working capital investment}$

6.1.1 Fixed capital investment

Manufacturing fixed-capital investment represents the capital necessary for the installed process equipment with all auxiliaries that are needed for complete process operation.

Total fixed capital investment = Direct capital investment + Indirect capital investment. Purchased Equipment: - The cost of purchased equipment is the basis of several pre-design methods for estimating capital investment. For the same capacity of new equipment, we can get the overall cost from some studies and vendors or can be calculated using cost indexes.

Present cost = $\text{past index} \times \text{present index} / \text{past index}$



Equipment name	Material of construction	Capacity in(m ³)	Quantity	Purchased cost(\$)	Total cost(\$)
CH-storage tank	Carbon steel	6	1	\$95,000	\$95,000
Dried-CH storage tank	Carbon steel	6	1	\$40,000	\$40,000
Belt conveyor	Carbon steel	8.7	1	\$49,000	\$49,000
Centrifugal pump	Carbon steel	6.5	4	\$24,500	\$98,000
Water storage tank	Carbon steel	6	3	\$28,600	\$85,800
Mixing tank	Carbon steel	6.5	2	\$75,000	\$150,000
Air compressor	Carbon steel		1	\$27,000	\$27,000
Hydrolysis tank	Carbon steel	6.5	2	\$32,000	\$64,000
Stirred reactor	Carbon steel	9.1	2	\$150,000	\$300,000
Control valve	Carbon steel		5	\$30,500	\$152,500
Sulfuric acid recovery tank	Carbon steel	6.5	2	\$80,000	\$160,000
Cross flow heat exchanger	Carbon steel		3	\$50,000	\$150,000
Sulfuric acid storage tank	Carbon steel	8.23	2	\$15,500	\$31,000
Separator	Carbon steel	6.7	2	\$15,000	\$30,000
Fly ash tank	Carbon steel			\$1000	\$1000
Filter	Carbon steel	5.5	2	\$20,000	\$40,000
Steam turbine	Stainless steel		1	\$23,000	\$23,000
Boiler	Stainless steel		1	\$40,000	\$40,000



Fermenting tank	Carbon steel	8.22	2	\$3000	\$6000
Distillation column	Stainless steel	8.67	2	\$70,000	\$140,000
Condenser	Stainless steel	4.7	2	\$10,000	\$20,000
Bottom recovery tank	Carbon steel		12	1	\$25,000
Ethanol recovery tank	Carbon steel	6.35	1	\$70,000	\$70,000
Total of purchased equipment cost					\$1,797,300

Table 6. 1 purchased equipment cost

Purchased equipment cost = \$1,797,300

Since purchased equipment cost (PEC)

= (15-40) % fixed capital investment (FCI). Choose average value

27.5% .be chooses.

$$FCI = PEC / 0.275 = \$1,797,300 / 0.275 = \$6,535,636.3$$



Component	Range%	Typical	Cost =%FCI(\$)	Total (\$)
Direct cost				
Purchased equipment cost	15-40%	27.5	0.243* \$6,535,636.3	1,588,159.6
Purchased equipment installation	6-14%	10	0.0884*\$6,535,636.3	577,750.2
Piping (installed)	3-20%	10	0.0884* \$6,535,636.3	577,750.2
Instrumentation and controls(installed)	2-8%	5	0.0442*\$6,535,636.3	288,875.1
Electrical (installed)	2-10%	6	0.053*\$6,535,636.3	346,388.7
Building (including service)	3-18%	5	0.0442*\$6,535,636.3	288,875.1
Yard improvement	2-5%	3	0.0265* \$6,535,636.3	173,194.4
Service facilities	8-20%	12	0.1062*\$6,535,636.3	694,084.6
Land	1-2%	1.5	0.0132*\$6,535,636.3	86,270.4
Total direct cost				4,621,348.3
Indirect cost				
Engineering and supervision	4-21%	12	0.1062*\$6,535,636.3	694,084.6



Construction expense	4-16%	10	0.0884*\$6,535,636.3	577,550.2
Contractors fee	2-6%	4	0.0354*\$6,535,636.3	231,361.5
Contingency	5-15%	8	0.0707* *\$6,535,636.3	462,069.5
Total indirect cost				1,965,265.8
Total		113		\$6,535,636.3

Table 6.2 fixed capital

investment

6.1.2 Working Capital

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

Total fixed capital investment is the sum of direct capital investment and indirect capital investment.

Direct capital investment = \$ 4,621,348.3

Indirect capital investment = \$1,965,265.8

Total fixed capital investment = \$ 4,621,348.3 + \$1,965,265.8 = \$ 6,535,636.3

$$\text{Total capital investment (TCI)} = \text{FCI} + \text{WC}$$

$$\text{Working capital investment (WC)} = 15 \% (\text{TCI})$$

$$\text{TCI} = \text{FCI} + 0.15\text{TCI}$$

$$\text{TCI} - 0.15\text{TCI} = \text{FCI}$$

$$0.85\text{TCI} = \text{FCI}, \text{TCI} = \$ 6,535,636.3$$

$$\text{FCI} = 0.85 * \$ 6,535,636.3$$

$$= 5,555,290.85$$

$$\text{WC} = 0.15 * \$5,555,290.85 = \$833,293.6$$



6.2 Total Product Cost

The total production cost is generally divide into the categories of manufacturing costs and general expenses. Total production cost is broken down into two: manufacturing cost and general expenses. The manufacturing costs are also sub divided into fixed operating costs, variable operating costs and Plant overhead costs.

6.2.1 Manufacturing cost

Direct Production Costs

Raw materials	Annual Quantity	Unit Cost \$/kg	Annual Cost (\$)
Coffee husk waste	4,660,224kg	0.0081	37,747.8
98% sulpheric acid(H ₂ SO ₄)	39611.904	0.08	3,168.9
Sodium Hydroxide (NaOH)	36802.1739	0.04	1,472.086
Yeast (Saccharomyces cerevisiae)	354400	0.045	15,948
Yeast extracts (Agar)	217645	0.22	43,529.8
Urea	1769851.52	0.5	884,925.76
Dextrose sugar	414921.5	0.21	87,133.4
Hydrochloric acid(HCl)	42070	0.29	12,200.3
Total			\$1,086,126.04

Table 6. 3 material cost

Total raw material cost = \$ 1,086,126.04

Raw material = 10-50% of total product cost

Raw material cost = 40% of total production cost (TPC)

TPC = 1,086,126.04/0.4

= 2,715,315.15



No	Types of manpower	Amount	Monthly Salary(ETB)	Total monthly salary(ETB)
1	G. Manager	1	20,000 Birr	20,000 Birr
2	V.G. Manager	1	14,000 Birr	14,000 Birr
3	H.R. Manager	1	10,000 Birr	10,000 Birr
4	Production Manager	1	12,000 Birr	12,000 Birr
5	Marketing Manager	1	10,000 Birr	10,000 Birr
5	Financial Manager	1	8,000 Birr	8,000 Birr
6	Design department	2	5000 birr	10,000 Birr
7	Workshop	10	1500 birr	15,000 Birr
8	Secretary	6	1750 birr	1020
9	Chemists	4	3000 birr	12000
10	Quality control department	2	6000 birr	12000
11	Process Supervisor	1	6000 birr	6000
12	Purchase and Sales	1	3250 birr	3250
13	Market Study	1	3000 birr	3000
14	Promotion and Advertising	1	3000 birr	3000
15	Chief Engineer	1	6500 birr	6500
16	Operators	8	2000 birr	16000
17	Nurses	4	2500 birr	10,000
18	Medical Doctor	1	7000 birr	7,000
19	Security Guard	12	1500 birr	18,000



20	Janitor	14	1000birr	14,000
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Table 6. 4 operating cost

Direct production costs	% it accounts	Considered percentage	Annual Cost(\$)
Raw materials	(10-50% (TPC)	20% (TPC)	543,063
Operating labor	10-20% (TPC)	15% (TPC)	407,297.3
Direct supervisory and clerical labor	10-25% (TPC)	16% (OPL)	64687.56
Utilities	10-20% (TPC)	15% (TPC)	407,297.3
Maintenance and repairs	2-10% (TFI)	6% (FCI)	162,918.9
Operating supplies	10-20% (cost of maintenance)	15% (MC)	407,297.3
Laboratory charges	10-20% (OPL)	14% (OPL)	380,144
Patents and royalties	0-6% (TPC)	3% (TPC)	81,459.5
Total direct production cost			2,823,927.7

Table 6. 5 direct production cost

Fixed charges 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 a building value.

1. Local taxes (1-4%) of fixed capital investment
2. investment
3. Insurance (0.41%) of fixed capital investment
4. Rent (8-12%) of rented building. Fixed charge calculation



$$5. \quad \text{Depreciation} = 10\% \text{FCI} + 2.5\% \text{ of building value} = 0.1 * 6,535,636.3 + 0.025 * 288,875.1 = \$660,785.5$$

$$6. \quad \text{Local taxes} = 2\% \text{ FCI} = 0.02 * 6,535,636.3 = \$130,712.726$$

$$7. \quad \text{Insurance} = 0.5\% \text{FCI} = 0.005 * 6,535,636.3 = \$32,678.18$$

$$8. \quad \text{Rent} = 10\% \text{ of value of rented land and buildings} =$$

$$0.1 * (86,270.4 + 288,875.) = \$37,514.54$$

Total fixed charge cost (\$) = Depreciation + Local taxes + Insurance + Rent

$$= \$660,785.5 + \$130,712.726 + \$8,789.6 + \$32,678.18 = \$832,965.5$$

Plant overhead Cost: - 50-70 % (of cost for operating labor, supervision and maintenance) Plant overhead cost

$$= 60 \% (\text{operating labor cost} + \text{supervision cost} + \text{maintenance cost})$$

$$= 0.6 * (407,297.3 + 64,687 + 462,918.9) = 454,527.54$$

Manufacturing cost = Direct production cost + fixed charge cost + plant overhead cost

$$= \$2,715,315.15 + \$832,965.5 + \$454,527.54$$

$$= \$4,502,808.2$$

6.2.2 General expense

- A. Administrative costs (about 15% of costs for operating labor, supervision, and maintenance, or 2-6% of total product cost).
- B. Distribution and selling costs (2-20% of total product cost).
- C. Research and development costs (2-5% of every sales dollar or about 5% of total product cost).
- D. Financing (interest) (0-10 % of total capital investment)

$$\checkmark \text{ Administrative cost} = 15\% (\text{operating labor cost} + \text{supervision cost} + \text{maintenance cost})$$

$$= 0.15 (407,297.3 + 64,687.5 + 462,918.9)$$



$$= \$ 140,235.5$$

- ✓ Distribution and selling cost = $0.11 * \$2,715,315.15 = \$298,684.6$
- ✓ Research and development = $0.05 * 2,715,315.15 = \$135,765.75$
- ✓ Financing(interest) = $0.05 * 6,535,636.3 = \$326,781.815$

E. General expense = administrative cost + distribution and selling cost + research and development cost + financing expense

- ✓ General expense = $\$140,235.5 + \$298,684.6 + \$135,765.75 + \$326,781.815 = \$ 901,467.66$
- ✓ Total production cost = manufacturing cost + General expense
 $= \$ 4,502,808.2 + \$901,467.66$
 $= \$5,404,275.86$

6.3 Economic Evaluation

Net Income, Payback period and Return on Investment

Type of product bioethanol

- ✓ Amounts of produced = 7,000,000 liter/year
- ✓ 1dollar = 43birr
- ✓ Price of 96% of ethanol = 20birr/liter based on the current price set by sugar corporation.
- ✓ 1dollar = 43birr

$$X = 50\text{birr/liter.} \quad X = \$ 1.16$$

1. Annual revenue = $7,000,000 * 1.16 = \$8,139,534.9$

2. Total production cost = $\$5,404,275.86$

3. Gross annual profit = annual revenue – total production cost

$$= \$8,139,534.9 - \$5,404,275.86 = \$2,735,259$$

4. Income tax on gross profit = 34% gross annual profit

$$= 0.34 * \$ 2,735,259 = \$929,988.06$$

- ✓ Net income = gross annual profit – income tax on gross profit

$$= \$ 2,735,259 - \$929,988 = \$1,805,270.9$$

- ✓ Rate return on investment (ROR)



$$= 1,805,270.9/6,535,636.3 * 100\%$$

$$= 27.6\%$$

✓ Payback period = TCI/Net profit

$$= 6535,636.3/1805,270.9$$

$$= 3.6 \text{ year}$$

So payback period of the project estimated to be one year and four month

✓ Break even analysis = FCI/TPC-WC

$$= 5,555,290.85 / (5,404,275.86 - 833,293.6)$$

$$= 1.215 \text{ year} = 1 \text{ year}$$

Fixed capital investment (FCI)	\$5,555,290.85
Working capital(WC)	\$ 833,293.6
Total capital investment(TCI)	\$6,535,636,3
Total production cost(TPC)	\$5,404,275.86
Depreciation	\$660,785.5
Total income	\$8,139,534
Gross profit	\$ 2,735,259
Net profit	\$1,805,270.9
Rate of return(ROR)	27.6 %
Payback period	3.6 year
Breakeven point	1 year

Table 6. 6 summary of economic analysis



CHAPTER SEVEN: PLANT LAYOUT AND SITE

LOCATION

7.1 Plant Site

Site criteria should be identified and ranked in terms of importance. These criteria provide guidance in the selection of specific plant site and help full when evaluating competing location. Feedstock and energy cost are typically among the highest input costs but other factor are in important in deterring production cost estimate, profitability and competitiveness of the plant. Proper siting of an ethanol plant, including the optimum location of the plant on the site itself, is among the most important aspects of project development. This process should be based on broad range of parameter designed to optimize the economic viability of the plant and the opportunity for successful sustained operation of the facility. The following criterion should be considered general site location factor. Process technology, feedstock operation and other factor that may represent unique locational factor or opportunities should also be considered when present.

7.1.1. Feed stock

Grain is the primary feedstock used in ethanol production. Other feed stocks will vary by region. Any type of grain containing starch can be used to produce ethanol. Biomass materials vary considerably in potential ethanol yield and should be carefully evaluated. In Jimma coffee husk is very available feedstock in some areas of the country other grains including wheat, barley and grain sorghum are used as feedstock for ethanol. Some process technologies allow multiple grain feed stocks to be used in the same plant. Grain fractions, out of condition grain and off spec grain can be used for ethanol production in some cases. However, most process technologies are designed to use a single type of grain that meets specific grading parameters. Careful attention should be given to the cost and availability of the primary feedstock. In many grain ethanol plants, the feedstock cost can account for 50-70 percent of the ethanol input cost depending on the price range. Biomass material demonstrating potential as ethanol feed stocks include wood, waste, paper, leafy crop material, rice or wheat straw and other renewable matter. Several process technologies are currently available for conversion of biomass material into ethanol.

When evaluating net feedstock cost, project developers should consider the following factor, regardless of feedstock:



- ✓ Price history, production patterns and trends in the area from which the ethanol plant is most likely to acquire the primary feedstock.
- ✓ The quantity of feedstock historically available in the area and other sources of competition for the feedstock
- ✓ Location of the ethanol plant in relation to proximally of the feedstock and methanol of transporting feedstock to the plant on a year around basis.

7.1.2. Energy requirement

The energy requirement for ethanol production has improved markedly during the past decades due to a variety of technology and plant design improvement. The energy needed to produce a gallon of ethanol has decreased nearly 50% over the past fifteen years and that trend is likely to continue as process technology improves. It is used in the ethanol production process and in drying the related grain co - product. Due to the significant cost of drying wet distiller's grains some plant are designed to minimize this option provided they are located in an area where this product can be market in wet form. However, the process energy cost must carefully evaluated since it will likely represent the second largest input cost in an ethanol plant. The historic price of electricity has not varied in most states like the price of natural gas. The operating costs for electricity in a medium size grain ethanol plant may be nearly \$2 million annually but this cost can be managed via contract options. Increased demand for coal may also affect the long-term price of energy at facilities that opt for coal as a boiler fuel. When evaluating potential ethanol plant sites, energy cost factors for consideration should include the following:

- ✓ Proximity to energy source (natural gas pipeline, coal, propane, co-generation, etc.)
- ✓ Historic price, availability and reliability of supply
- ✓ Emission control costs and permit issuance time for selected energy sources
- ✓ Electric utility rates
- ✓ Contract options for all energy sources

7.1.3. Transportation

The cost of transportation is important to plant input costs and marketing costs. With regard to marketing costs, an initial market assessment conducted during a pre-feasibility or feasibility study phase should identify primary markets for the plant. Depending on proximity of the plant to population centers, marketing costs may be based on a variety of transportation modes. Ethanol has historically been shipped to markets via truck, rail and barge. The location of the plant should take into consideration the model of transportation



by which the bulk of finished product will move to market. Rail access is often viewed as an essential requirement for large-scale ethanol plant. The product will move to market. Rail access is often viewed as an essential requirement for large-scale ethanol plant. Ethanol marketing companies can assist with this analysis and with identification of target market. Transportation related factor for consideration should include:

- Major highly and interstate access to target market.
- Potential for disruption of travel on these based on projected construction and historic weather patterns.
- Proximity of mainline rail to site and estimated cost of related rail siding and switching services.
- Orientation of highway and rails access in relationship to the plan location on site.
- Number of transportation providers in each sector.
- Option for competitive transportation services.

7.1.4. Water Requirements

Water quality, quantity and infrastructure for handling water treatment are important factors in site selection. The water requirements factor into capital cost of the plant, operating costs and permit issues that will become important when the plant is constructed. During the past decade, new process technology has reduced the volume of process water required in ethanol plants and has minimized the water discharge volume. An understanding of specific water use and discharge requirements is useful during the site selection process. Local resource agencies can provide information about water use and potential discharge restrictions.

Depending on the site, there are typically several water related option to be considered when evaluating sites:

- Potential availability and cost of water provided by a community water system.
- The cost, volume, quality and accessibility of water from onsite well.
- Cooling water availability from river frontage sites.
- Overall water quality (pH, mineral content, etc.)
- Existing infrastructure availability for water supply and waste water

7.1.5. Community Considerations

The project development team may include representatives of the community near which the ethanol plant site is located. In this case, the representative may already be interacting



with community officials. Interaction with community official and representatives can play an important role in determining the extent to which the community will support the project. Project support may be in the form of tax incentives, site considerations, zoning change or a variety of other concessions that vary in value. Community residents will be far more likely to support the project, and less likely to complicate permit and zoning processes, if they understand the positive, and potentially negative, impact of the proposed plant. Potential negative impact can be minimize with proper planning and site selection.

7.1.6. Factors Related to Site Selection

In addition to factors discussed above, there are other aspects of the site selection process. Several of these were briefly cover in the pre-feasibility study discussion. During the feasibility study, these factors need additional attention.

Markets Ethanol:- Ethanol produced from grain via a dry-mill process yields three primary products: ethanol, distiller’s grains, and carbon dioxide. On a weight basis, approximately one third of a bushel of grain converted to each of these products. However, the value of each of these products is significantly different. An ethanol market assessment is typically part of the feasibility study.

Markets Distillers Grains;- Distillers grains represent the second most valuable product in conventional ethanol plants. Distiller’s grains can dried for shipment to markets in the area as well as remote markets, depending on demand.

Markets Carbon Dioxide:- Carbon dioxide is the least valuable of the three products typically produced at a grain ethanol plant. However, many ethanol producers find local market outlets for this product. Carbon dioxide is transportation sensitive due to its relatively low value. For that reason, local markets should be assessed. Local markets for carbon dioxide may include:

- ✓ Food processing companies
- ✓ Beverage or bottling companies
- ✓ Industrial gas companies
- ✓ Oil and natural gas recovery operations in nearby fields

7.2. Site Size and Location

Site size is often determine by geographic constraints, land cost and proximity to preexisting infrastructure. The actual plant footprint for an intermediate size ethanol plant is approximately 10-15 acres depending on plant technology and configuration. However, factors such as air permit considerations, rail and on-site transportation patterns, in



addition to future plant expansion needs; based on availability of raw material, transportation facilities, water requirement, sufficient manpower, and demands, the site selected for ethanol plant is Jimma

Factors to consider when determining plant size and location include:

- ❖ Prevailing wind patterns and proximity to community or inhabited dwellings

Desirable site buffer to accommodate aesthetic goals and air permit requirements

- ❖ Adequate space for on-site road and rail configurations and expanded storage
- ❖ Additional space for waste water or other pollution mitigation options
- ❖ Sufficient space to accommodate plant re-configuration to meet future needs dictated by change in production output or regulatory changes plant layout.

7.3 Plant Emission and Pollution Control

Determine the direct environmental effects of ethanol production are complex. Environmental effects of using bioethanol vary, depending on the fuel itself, vehicle technology, vehicle tuning and driving procedure. In addition, agricultural production particles and the design of ethanol production plants differ largely (18). Water issues are important concern of both, ethanol processing and use of ethanol. The water consumption for the production of bioethanol is considerable high. There by, much water used for feed stock production. The amount of water used for agricultural depends on the humidity /aridity of the cultivated region and on the water demand of the feedstock type. Also for the conversion process, much water needed. The quantity of water needed for the ethanol production process depends on the design of the production plant. Modern technology and design can substantially reduce the amount of fresh water needed by a standard alone ethanol plant. There is zero discharge plants in operation, that recycle virtually all of the water used in production, limiting the need for large supplies (19) However, there are different water uses in atypical ethanol plant. The first water use in atypical ethanol plant in non-contact water, primarily used for cooling. The second use is for liquefaction of the feedstock. Water must be clean and treated so that there is no microbiological contamination in the fermentation process

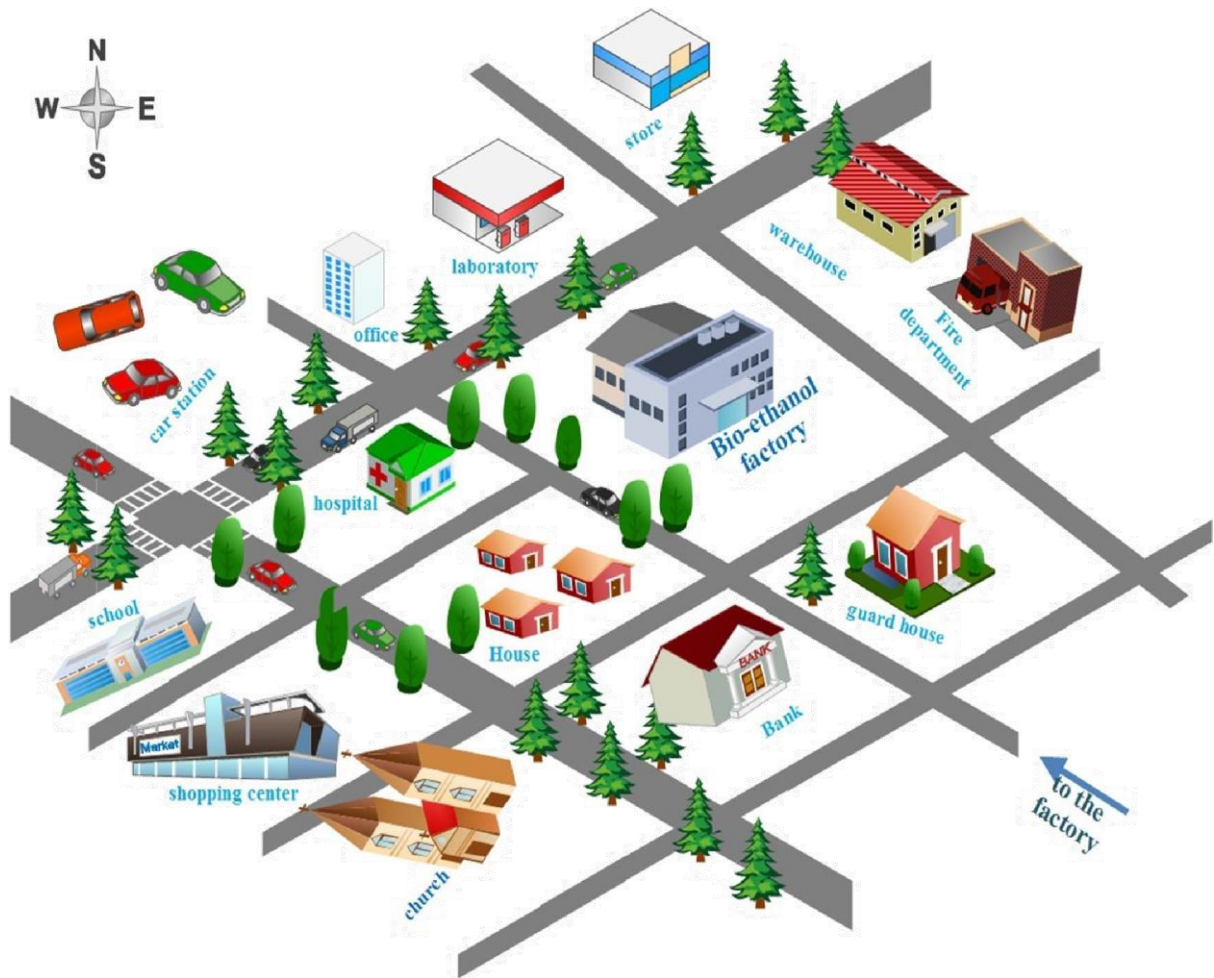


Figure 7. 1 Plant Layout



CHAPTER EIGHT: CONCLUSION AND RECOMMENDATION

8.1 CONCLUSION

Coffee husks is promising lignocellulosic feedstock for the production of bioethanol fuel. It is major solid residues from the handling and processing of coffee. To proceed the fusibility of coffee husk, six experiments were conduct with in size in laboratory. In addition to varying their size and concentration through the time of hydrolysis. The lab experiments which produce in laboratory were (1%, 0.5mm) , (3%,0.5mm) (5%, 0.5mm) and (1%, 1mm) , (3%, 1mm) and (5%, 1mm). From that experiment, we get high amount of converted sugar from (3%, 0.5mm). From 100g of coffee husk powder, 68.28% of yield (bioethanol) obtained. From this, we conclude that the concentration of acid and the size of coffee husk have effects on the yield. The result gained by the literature and the yield we obtained at the end of yield have almost approximated value.

Bioethanol, which produced in the laboratory was characterize by different methods like, PH , physical properties(ash content, volatile matter, fixed carbon content, and etc..) and chemical properties(by chromic acid).the result of our physical characterization and PH value are almost the same with the literature result, and also chromium characterization gives us color change. Based on the laboratory experimental results, the economic feasibility of the ethanol plant discussed. The Ethanol plant production capacity is 7,000,000-liter ethanol per year and the net profit of this plant is \$1,805,270.9. The plant lifetime 20 years and its payback period is 1.38 year. Jimma is select for plant location, based on availability of raw materials and other facilities. Fuel derived from cellulosic biomass is essential in order to overcome our excessive dependence on petroleum for liquid fuels and reduces building up of greenhouse gases that cause global climatic change and our research used to protect environment by using waste coffee husk as useful source of energy. The conversion offers the potential for radical technical advancement through application of powerful tools of modern biotechnology to realize truly low cost.

8.2 RECOMMENDATION

Based on our laboratory investigation we give the following recommendation. The plantation of coffee crop is dramatically increasing from year to year. At the same manner the coffee husk increasing. Therefore, the whole community of the country attends to start up bioethanol plant, which results in job opportunity for society.

- ✓ The development of processes for valorization of coffee husks to bioethanol is feasible in terms of energy sector and an environmental friendly process for waste management. So, this research should be integrated to large scale in our country, which can solve the shortage of energy, and environmental pollution as well and there should be an economic feasibility analysis on a large, scale basis of the overall conversion of coffee husk residue to bioethanol for the purpose of commercialization.
- ✓ It is also possible to produce other very important products from coffee husk rather than bioethanol.
- ✓ Optimization of hydrolysis variables carried out in this study, but further study recommended obtaining high yield of bioethanol.
- ✓ A detailed economic feasibility study in the production process recommended, since it is commercially profitable.
- ✓ The temperature used for hydrolysis of the pretreated sample was 99°C but we recommended using 130°C temperature for 3% of sulphuric acid to get more yield of bioethanol.
- ✓ As coffee waste is a major pollutant to the environment, the government, investors, and experts should give higher attention in handling and utilizing these wastes.



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