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COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

Production of Bioethanol from Potato Peel.

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This Thesis Submitted to Wolkite University, College of Engineering and Technology, Department of Chemical Engineering Under Process Engineering stream in Partial Fulfillment of the Requirements for the Degree of Bachelor of science.

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August 2021

Declaration

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Acknowledgements

First of all, thanks to the almighty God for giving us the patience and strength to start and finalize this project. Secondly, we would like to express our deepest gratitude and heartily appreciation to our advisor Mr.Getu for his continuous guidance and support to complete our work. Thirdly, we would like to thank department of Chemical Engineering laboratory technicians for their cooperation during our experimental work. We also would like to express our gratitude to Food Process Engineering Department laboratory technicians for their support during our experimental work. Lastly, we would like thank our friends and peer group members for their cooperation up to last without any tiredness.

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List of Acronym and Abbreviations

BE	Break-even point
CO_2	Carbon dioxide
CO	Carbon monoxide
Cp	Specific Heat gravity
CEPCI	Chemical Engineer Plant Cost Index
FCI	Fixed Capital Investment
FCC	Fixed Charge Cost
GE	General Expense Cost
GHG	Green House Gas
NOX	Nitrogen Oxide
PEC	Purchased equipment Cost
Pm	Particular matter
POHC	Plant over Head Cost
Q	Heat Flow
Rpm	Revolution per minute
RORI	Rate of Return Investment
TPDC	Total plant direct cost
VLE	Vapor Liquid Equilibrium
VOC	Volatile Organic Compound
WC	Working capital cost
^{O}C	Degree Celsius

Abstract

Green plants and factory byproducts containing carbohydrate can be a source of a product like bioethanol. The major problem of these raw materials is the content and type of carbohydrate. In this study, potato peels was chosen as a carbon source; however, a pretreatment process is needed to convert starch of potato to fermentable sugar through hydrolysis.

Potato peels were washed, cut, dried at 103°C for 24h and ground to the particle size of 2 mm. After soaking in diluted acid for 24h, hydrolysis was carried out. The hydrolysis was carried out by using dilute acid hydrolysis process. And then separation of solid sludge from fermentable sugar in centrifuge was accomplished. Fermentation was then carried out by using saccharomyces cerevisiae. Then after simple distillation was carried out for bioethanol separation from water.

In order to obtain maximum ethanol, optimal value of factors for fermentation was determined in laboratory. The optimum combination of yeast amount and time at three levels for each was determined. The yeast amount of 3gm, 5gm and 7gm and fermentation time of 4days, 6days, and 8days was used. The group of experiment which contained 5gm yeast and 6days time produced maximum ethanol. Analysis of effect of yeast amount and fermentation time on ethanol production was carried out. The analysis was done by using Microsoft excel. The optimum amount of alcohol obtained was 50ml.

The economic feasibility of the project was analyzed. The result from the feasibility study indicated that the proposed work was feasible with rate of return (RR) 22.85% and the payback period of the project is estimated to be 2.89years.

Keywords: sugar, optimum, starch, fermentation and analysis.

CHAPTER ONE

1. INTRODUCTION

1.1. Back Ground of Bioethanol

Bioethanol, which is one of the energy sources, is known to be a potential alternative to petroleum derived fuels and has the potential to meet the increasing demand of energy for industrial processes, heating and transportation. And also can be used as an alternative fuel to gasoline. It can be produced by fermentation from several renewable sources, such as from potatoes, sugarcane and corn. Globally, there is a growing interest for the production of ecologically sustainable bio-fuels. In 2013, 24 billion gallons of bioethanol were produced worldwide (yacob, 2013).

Bioethanol could be produced from rich sources like corn, sugar beet, sweet sorghum, sweet potato or from the abundant cheap cellulosic feed stocks like wheat straw, switch grass, wood etc. known as cellulosic ethanol. In order to prevent the use of staple crops, agricultural wastes like corn cobs, Stover, sorghum stalks, potato peels and byproducts from sugar industries like sugarcane molasses etc. are considered as cheaper sources of bioethanol. Potato is high value crop as a food source. During processing of potato, potato peel are wasted; therefore, the waste from restaurant, hotels, chips shops and potato processors can be utilized as growth media for the fermentation processes.

Petrol and diesel are the most widely used fuels for automobiles in Ethiopia. Bioethanol can be blended with gasoline known as gasohol for use in vehicles. Ethiopia imports most of the oil from Middle East by spending valuable foreign currencies. If Federal Government regulations are adopted based on the Kyoto agreement, the mandatory blending of bioethanol with traditional gasoline in amounts up to 10% will result in a demand for large quantities of bioethanol. Many countries have implemented, or are in the process of implementing, programs providing for the addition of bioethanol to gasoline. Fuel ethanol production has increased remarkably due to the global demand to reduce oil importation, thereby contributing towards boosting rural economies and improving air quality (Arapoglou *et al.,* 2010).

Changing life style and craving for processed foods are factors responsible for the significant growth of global food processing industries. Among several varieties of processed foods, the products from potatoes are in great demand. Potato is a starchy tuber with carbohydrates constituting as much as of 13-30% with a little protein (0.7- 4.6%). The conventional peeling method presently followed in the processing plants for removing the potato peel, also result in the loss of some portion of the mash which is rich in starch (Chintagunta *et al*., 2015).

This research gives an insight about the production of bioethanol by using acid hydrolysis for the conversion of potato peel. The production of bioethanol from potato peels are attempted in this study. The fermentation was carried out by using *saccharomyces cerevisiae*. In addition to this the yield of bioethanol from potato peels was investigated at specific conditions.

1.2. Statement of Problem

The question of sustainable and cleaner energy resources has become prominent in the past few decades. However, the future of petroleum products reserve is uncertain with increase in price that makes the foreign currency expenditure intolerably high and affect transport tariff and price of other commodities. Wastes disposed from food processors, hotels, restaurants, cafeterias, and chips shops should be used to produce alternative energy. The surveys have taken in Wolkite University student cafeteria. From 750kg per day consumption of potato, about 150 kg potatoes peel is wasted. Since potato utilization per university schedule is eight times per month, about 1200 kg of potato peel is generated per month. This generated waste is directly disposed without any utilization. So, it affects environment because it is a source for nutrient leaching to ground and surface water, also produce odor and attract insects that cause different diseases such as bacterial ring rot and nematodes. As a result potato peel could decrease the dependence on fossil fuels and give an opportunity to use wastes disposed from potatoes as a carbon source for production of bioethanol.

1.3. Objectives

1.3.1 General Objective

The general objective of the study is to produce bioethanol from potato peel.

1.3.2. Specific Objectives

- To extract starch from potato peels.
- To evaluate the effect of yeast amount and time on fermentation process.
- To characterize the product in terms of density and color.
- To check economic feasibility of the project.

1.4. Significance of the Study

The production of bioethanol, a type of bioenergy has immense benefit such as;

Bioethanol manufactured from waste potato peels could serve as fuel volume extender, an oxygenator, and an octane enhancer. When blended with gasoline, it could increase the octane rating and the oxygen content of the fuel, which results in more complete combustion and reduction in exhaust emissions such as carbon monoxide and unburned hydrocarbons which have a problem.

To develop understanding on long-term bioethanol production and transport fuel substitution shifts in Ethiopia and thus provides a significant value to academic researchers, business societies, industrialists, policy makers, and all interested groups.

To strengthen policies and strategies promoting green economy using biofuels, as alternative energy source.

To use ethanol as a raw material for polymer, ester production and for utilization of germicide and also can be used as a solvent.

1.5. Scope of the Study

In this research potato peels are served as raw material for preparation of bioethanol and gives basic information on the development of bioethanol. This work will offer understanding on bioethanol in general and its status in Wolkite University. Recognizing the status in the states of potato peel in Wolkite University will be important to businesses to have a fundamental data and the opportunities. This research attempts to indicate the suggestions connected with the expanded bioethanol development and its use as it is not well understood in the country.

This research work involves the collection of potato peel from student cafeteria and lounge. Then after an analysis made to determine physical and chemical properties of potato peel used for the production of bioethanol as fuel and hydrolysis by using diluted sulphuric acid process and adjust the PH by using sodium hydroxide. Then preparing fermentation media and fermentation process was carried out. Finally, the fermented product distilled and physical and chemical characteristics of produced product are analyzed by using different analyzers, such as alcoholmeter and spectroscopy.

1.6. Limitation of the Project

Production of bioethanol is a very interesting process, since it creates wealth from waste. This project tried to explain the way of production processes based on laboratory result. But during the processes there were a number of limitations that encountered us to deal with. Some of them are listed below.

1. Lack of well-equipped laboratory for the production of bioethanol.
2. Lack of prior laboratory experience.

CHAPTER TWO

2. LITERATURE REVIEW

This chapter consists of two sections; the first section presents background information on bioethanol, feed-stocks, pretreatments, hydrolysis, and methods of bioethanol fermentation from potato peel, producer microorganisms of bioethanol, and potato as a raw material for bioethanol production and the second part discusses global and local trends on bioethanol production.

2.1. Definition of Bioethanol

The ethanol obtained from biomass based waste materials or renewable sources is called as bioethanol. It can be used as a fuel, chemical feedstock, and solvent in various industries. It has certain advantages as petroleum substitutes, as alcohol can be produced from a number of renewable resources. Alcohol as fuel burns cleaner than petroleum which makes it environmentally more acceptable. It is biodegradable and thus, keeps a check on pollution and it is far less toxic than fossil fuels (Domínguez-Bocanegra *et al*., 2014).

Ethanol is a clean-burning high-octane fuel that is produced from renewable sources. Because ethanol can be produced domestically in most countries; it helps reduce dependence upon foreign sources of energy for these countries. Ethanol is beginning to be used all around the world as a transportation fuel, and it has some distinct advantages. Fuels that burn too quickly make the engine "knock", a characteristic rattling sound. The higher the octane rating, the slower the fuel burns, and the less likely the engine will knock. When ethanol is blended with gasoline, the octane rating of the petrol goes up by three full points, without using harmful additives. Similar to the case of biodiesel, adding ethanol to gasoline "oxygenates" the fuel. It adds oxygen to the fuel mixture so that it burns more completely and reduces polluting emissions such as carbon monoxide (Cellulosic Ethanol, 2010).

2.2. History of Bioethanol

Ethanol is an important chemical product with emerging potential as bio fuel to replace the fossil fuel. An eco-friendly bioethanol is one of the alternative fuels that can be used unmodified petrol engines with current fueling infrastructure and it is easily applicable in present combustion engine as mixing with gasoline (Hansen et al., 1985).

Ethanol produced by microbial fermentation of biomass is used primarily as a substitute for gasoline, usually blended, although it can also be used lonely in industrial use or rocket fuel.

In developing countries, it is commonly used to replace kerosene for cooking and illumination. Besides being a renewable energy source, bioethanol has other advantages over fossil fuels: it emits less CO_2 when burned (Brown et al., 1998), which in addition is compensated by CO_2 uptake from the biomass; it does not emit toxic gases (such as CO and nitrate oxides) or particles when burned; less energy is required to produce ethanol than the equivalent amount of gasoline; it is rapidly biodegraded in the environment; it has a higher octane rating than gasoline (Bailey, 1996).

2.3. Feed stocks for bioethanol production

Feed-stocks are typically grouped under the heading biomass and include agricultural residues, wood, municipal solid waste and dedicated energy crops (Kim and Dale, 2004). Biomass is seen as an interesting energy source for several reasons, the main reason being the contribution provided by bioenergy to sustainable development (Sanchez and Cardona, 2008). Resources are often available locally, and conversion into secondary energy carriers is feasible without high capital investments (Lin and Tanaka, 2006).

Different feedstock types are available for the production of bioethanol as it can be derived from any biological raw materials that contain sugar, such as sugarcane, sugar beets and potatoes, or materials that can be converted into sugar from starch or cellulose, such as corn, wheat and other cereals (Yacob, 2013). Ethanol may be obtained from the agricultural products, products from food and biomass processing industries that are divided into three groups: raw sugar e.g. sugar beet and sugar cane, raw starch e.g. corn, rye, and triticale and lignocellulose materials such as grass, wood (Gumienna *et al*., 2015).

2.3.1. Starch based feedstock

Starch containing crops form an important constituent of the human diet and a large proportion of the food consumed by the world's population originates from them. In spite of the large number of plants able to produce starch, only a few plants are important for industrial starch processing. The major industrial sources are maize, tapioca, potato, and wheat (van der Maarel *et al*., 2002). Amongst various starchy materials available throughout the world; corn, wheat, potato, and purified starch have been successfully utilized for the commercial production of bioethanol (Pervez *et al*., 2014). Root and tuber crops contain on average 70-80% water, 16-24% starch, and trace quantities of proteins and lipids (Peroni *et al*., 2006).

Grains. The most common grains used in alcohol fuel production are corn, barley, wheat and sorghum. With the exception of sorghum, all of these grains have been used extensively for years as feedstock for the production of beverage grade alcohols. Now, with the new demand for non-fossil liquid fuels, these same grains are being called upon as basic feedstock for production of fuel grade alcohols as well. At least in the early stages of the small scale ethanol production movement, grains have been the most popular and widely used feedstock of all varieties mentioned (U.S. Department of Energy, 1982).

Tubers. The most common tubers used in alcohol fuels production are potatoes and sweet potatoes. Both are common farm products containing high concentrations of starch and are excellent feedstock for conversion to alcohol fuels.

Nevertheless, despite of using staple crops for ethanol production, wastes coming from staple crops could be used for ethanol production. During starch and bioethanol processing from cassava in Asian countries like Thailand and Indonesia, enormous amounts of waste consisting of peels and pulp are generated. In Nigeria, the world leader in cassava production, cassava is mainly processed into grain (popular West African food made from cassava tubers) by micro, small and medium scale enterprises and for every unit of raw cassava processed, there is generation of 30%, 20% and 16% of solid (mainly peels and pulp), liquid and gaseous waste (moisture and cyanide), respectively (Moshi *et al*., 2015).

2.3.2. Sugar based feedstock

In sugar crops, the majority of the six-carbon sugar units occur individually or in bonded pairs. Once a sugar crop has been crushed to remove the sugar, no additional processing is

needed prior to fermentation since the six-carbon sugar units are already in a form that the yeast can use. This fact is both an advantage and a disadvantage. Preparation of the feedstock for fermentation involves comparatively low cost equipment, labor, and energy costs, since the only major steps involved are milling and extraction of the sugar. However, sugar crops tend to spoil easily. Numerous types of microorganisms, including the type of yeast that produces ethanol thrive on these crops during storage because of their high moisture and sugar content.

Sugarcane: Sugarcane is considered as a favorable feedstock because of its high yield of sugar per acre, as high as 50 tons per acre per year and a correspondingly high yield of crop residue, known as bagasse that can be used as a fuel for production of process heat. The major drawback with this feedstock is the limited availability of land suitable for economical cultivation.

Brazil is the largest producer of sugarcane with about 27% of global production and a yield of 18 million gram of dry sugarcane per hectare, and highest yield occurs in Peru, which produces more than 32 million gram of dry sugarcane per hectare (Kim and Dale, 2004). In Asia countries like India, Thailand, and Philippines, sugarcane is produced on small fields owned by small farmers. For example, India has around seven million small farmers with an average of around ¼ hectare sugar cane fields (Ayele, 2011).

Ethiopia is endowed with large areas of suitable low lands, rivers and conductive climate for sugar cane growth. The climate and soil types in the country have both proven to be highly conducive for sugar cane growth and productivity. However, the total area developed for the production of sugar cane in the country is only about 8% of the total identified suitable areas. Experiences of existing sugar factories show that because of the suitable soil, adequate water and conductive climate, an average sugar cane production per hectare per month of the land under irrigation is very high as compared to other countries (Ethiopian Investment Agency, 2012).

2.4. Potato

Potatoes are starchy crops which do not require complex pre-treatments. Potato is a tuberous crop vegetable from the perennial *Solanum tuberosum* of the *Solanaceae* family. Potato is composed of 80% moisture, 18% starch and the remaining are protein, fat and minerals and is a

high value crop as a food source. Although potato is a high value product, the cost of bioethanol production can be decreased by using wastes from the potato industry (Abouzied and Reddy, 1986).

Potato is an important food and cash crop especially on the highland and mid altitude areas of Ethiopia. Potato provides food and income as a cash crop for over 2.3 million households in different part of Ethiopia. In recent years, potato production has dramatically increased by about 64%, from 349,000 tons in 1993 to 572,332 tons in 2010. Potatoes are mostly consumed after boiling and are incorporated as an ingredient. Nevertheless, there is an increasing demand for potato as an ingredient in other fast foods that entail salad and processed products such as French fries and crisps, as a result of dietary diversification among urban dwellers, emerging fast food restaurants and roadside small scale fryers (Mitiku *et al.,* 2015).

The direction of waste potatoes and potato peels for animal feed may be a risky option. Firstly, the material as it comes out as a waste has high moisture content, 70-80% which limits its value as an animal feed. Drying might prove very costly and increase significantly haulage costs. Second, the amount of protein, 8%, of dry matter is considered low for animal feed even for ruminants. However, this level may be enhanced by appropriate semisolid fermentation, (Han and Callihan, 1974) especially with the use of edible basidiomycete strains (*Lentinula edodes*, *Pleurotusostreatus*) which contain powerful lignocellulolytic enzymes (Arapoglou *et al*., 2010).

2.5. Pretreatments

Pretreatment of biomass is technically challenging and forms a large part of the process cost and therefore will need to be optimized prior to commercialization. Due to the different types of carbohydrates contained in biomass, a package of enzymes or microbes will be required for hydrolysis and fermentation; this package is a significant process cost and requires optimization. Pretreatment must meet the following requirements: Improve the formation of sugars or the ability to subsequently form sugars by acidic or enzymatic hydrolysis; avoid the degradation or loss of carbohydrate; avoid the formation of byproducts inhibitory to the subsequent hydrolysis and fermentation processes. Physical, chemical, physio-chemical and biological processes have been used for pretreatment (Wondale, 2012).

The pretreatment techniques that can be used include acid, alkaline, biological pretreatment, wet oxidation, organosolv, ozonolysis, ultrasound pretreatment and hydrogen peroxide with metal

salts pretreatment. These methods are significantly different from one another in terms of reaction conditions, process efficiency and complexity (Ramadoss and Muthukumar, 2015). In addition to these pretreatments the raw material should be washed and reduced in size.

2.6. Hydrolysis

Acids have been used to catalyze the hydrolysis of starch in starch cookers operating at temperatures of 50 to 150^{o}C, a process referred to as acid hydrolysis (Wondale, 2012). Acid hydrolysis aims the mass production of fermentable sugar from starch. Two main developing or commercialized acid hydrolysis processes of starch; Dilute Acid Hydrolysis Process (DAHP) and Concentrated Acid Hydrolysis Process (CAHP) have been introduced. CAHP is operated at the condition of high acid concentration (above 1M HCl) and at low temperature (below 70^{o}C), which takes a long reaction time. The neutralization and the separation of acid are the main problems in CAHP.

DAHP is carried in a few second or minute at high temperature (between 150 and 200 ^{O}C) and dilute acid (below 3wt %). DAHP involves the undesired byproducts from degradation, reversion and retro gradation while it has some merits on the hydrolysis rate and alleviation of the neutralization. Starch hydrolysis has been also performed at moderate temperature between 90 and 120 ^{o}C for analytical application. This takes about 3h to complete the reaction in the case of 0.7M HCl (Hong and Bae, 1994).

The dilute-acid and concentrated-acid hydrolysis are relatively mature techniques for which no major improvements are likely to happen. Nevertheless, the enzyme cost is still high for the enzymatic process. The cost of enzyme in the processes has been calculated to be 10-20% of the total ethanol production cost (Wondale, 2012). Acid hydrolysis is used for alcohol production from potato industry starchy waste. However, byproduct of acid hydrolysis has inhibitory effects on yeast growth. Neutralization of hydrolyzers and expensive constructional equipment are also indicated as disadvantages of acid hydrolysis in industry.

2.7. Fermentation of Potato peel

Fermentation is a metabolic process of microorganisms to obtain energy by breaking down organic compounds. While microorganisms derive their energy, byproducts are: lactic acid, butane, carbon dioxide, ethanol, and cellulose. In ethanol fermentation, derivation of energy

from sugars by either yeast or bacteria, produce carbon dioxide and ethanol. Because yeasts produce their energy without the need for oxygen, ethanol fermentation is a facultative anaerobic process (Izmirlioglu and Demirci, 2012).

Utilization of potato peels for high yield ethanol production is the main purpose of the fermentation of potato medium. Because potato is a starchy material the fermentation process of waste potatoes and potato peels starts with hydrolysis. To convert starch into the fermentable sugars, either acid hydrolysis or enzymatic hydrolysis needs to be performed.

The dilute-acid and concentrated-acid hydrolysis are relatively mature techniques for which no major improvements are likely to happen. Nevertheless, the enzyme cost is still high for the enzymatic process. The cost of enzyme in the processes has been calculated to be 10-20% of the total ethanol production cost (Wondale, 2012). Acid hydrolysis is used for alcohol production from potato industry starchy waste. However, byproduct of acid hydrolysis has inhibitory effects on yeast growth. Neutralization of hydrolyzers and expensive constructional equipment are also indicated as disadvantages of acid hydrolysis in industry. Fermentation methods are important aspects of ethanol fermentation. Batch, semi-continuous, and continuous processes have been applied in the ethanol industry. There are also some other fermentation types, such as immobilized cultures.

2.8. Producer Microorganisms of Bioethanol

Microorganisms, termed ethanologens, presently convert an inadequate portion of the sugars from biomass to bioethanol. There are a number of microorganisms that produce significant quantities of bioethanol (Ayele, 2011). Yeast is the most commonly used microorganism in fermentation processes. Yeasts are minute, often unicellular, fungi. The yeasts used are typically bakery yeasts.

Yeasts capable of fermenting the decaying biomass include, but are not limited to, *Saccharomyces cerevisiae* and *Saccharomyces uvarum*. Non-*Saccharomyces* yeasts, also known as non-conventional yeasts, are also used to make a number of commercial products. Some examples of non-conventional yeasts include *Kuyberomyces lactic, Yarrowiali polytica, Hansenula polymorpha and Pichia pastoris* (Wondale, 2012).

Microorganisms other than yeast can also be useful in making fermentation products. There are bacteria which are used in ethanol production called *Clostridium ijungdahlii*. Mid to long term technology under development are expected to improve the fermentation efficiency of the organism, producing higher yields in less time, and an organism requiring less detoxification of the hydro lysate (Wondale, 2012). Although *Zymomonas mobilis*, *Kluyveromyces spp.*, *Schizo saccharomyces pombe*, and some recombinant bacteria and yeast can ferment sugars to ethanol, *Saccharomyces cerevisiae* is still the standard microorganism in the industry (Kunz, 2008).

2.9. Characteristics of Bioethanol

The physical and chemical properties of the bioethanol directly influence the combustion process, the performances and the efficiency of the engine.

2.9.1. Physical Properties

Bio-ethanol is a colorless liquid, with specific scent. In storage and manipulation conditions, bioethanol is a stable product if it is stored in sealed tank at room temperature, otherwise appears the risk of water vapors absorption from the air. Also, from physically and chemically stability point of view, bio-ethanol does not suffer accidental polymerization.

Bio-ethanol contains acetic acid and therefore it corrodes aluminum alloys. It also absorbs the lead in alloys and finally the surfaces become porous; same phenomena appear on zinc alloys (Al and Zn). In order to avoid this issue, it is recommendable a nickel cladding for all those surfaces. Same phenomena may appear on plastic parts of carburetors or injection systems as the carburetor bowl, fuel pump and injector inside parts, filters or any plastic – rubber gaskets. It is recommendable to be manufactured of nylon or rayon. Thus, different part of the classic fueling systems, carburetor or injection systems, must be replacement or protected for ethanol use. Other physical properties of bio-ethanol are: freezing point-13 ^{o} C, auto ignition point -363 ^{o} C, lower explosive limit (volume percent in air at 760 mm Hg and 20 ^{o} C) –3,3 %, higher explosive limit - 19 %.

2.9.2. Chemical Properties

Bio-ethanol has a low volatility expressed by a low value of the superficial tension at ambient temperature and also by a low value of the Reid vapors pressure. Thus, because the vapors pressure of the bio-ethanol (at 0ºC) is almost 4 times lower when compared to gasoline, the vaporization of bioethanol at temperatures below 10ºC becomes difficult. Different research's

show that this situation could be improved if very volatile additives would be used, such as isopentane or dimethyl ether (DME), or by a special intake air heating device use, especially in situations when higher bio-ethanol percentage in blend with gasoline or and pure bioethanol is used.

Using bio-ethanol in spark ignition engine with higher values of the compression ratio becomes possible due to its higher octane number with a research octane number value up to 106. Also the higher combustion rate of bio-ethanol is directly related with the engine efficiency improvement. If bio-ethanol is used as single fuel it has a disadvantage of the lower value of the caloric power registered compared to gasoline. As any other alcohol, the bioethanol has a low caloric power comparative to gasoline (26800kJ/kg and 43850kJ/kg for gasoline). This deficiency leads to the necessity of increasing the ethanol consumption and storage capacity on board of the vehicle; so that it requires larger fuel tanks in case of bioethanol use as a single fuel.

2.10. Uses of Bioethanol

The main use of ethanol is as a motor fuel and fuel additive. Ethanol and other alcohols can be used to power motor vehicles instead of gasoline. In almost all cases the ethanol is mixed with gasoline (Robati and Vazirzadeh1, 2013). Efficient method for conversion of biomass into fuel is by ethanol production because ethanol is an economical as well as environmentally friendly fuel. Ethanol has the advantages of being renewable, cleaner burning and produces no GHG (Altintas *et al*., 2002).

A number of market segments are available in the ethanol industry serving a wide range of uses in the medical sectors, pharmaceuticals, beverages, industrial, household, and transport uses.

The market potential for bioethanol is therefore not just limited to transport fuel or energy production but has potential to supply the existing chemicals industry and house hold uses. However, the most prevalent use of bioethanol in Ethiopia is as a transport fuel in spark ignition engine vehicles and the current amount of ethanol fuel blended with gasoline is 10% and the government is working to increase the share. The government is also working to start export in two years of time and to substitute household cooking fuel in the future (Yacob, 2013).

The other uses of ethanol are in alcoholic beverages. Alcoholic beverages vary considerably in their ethanol content and in the foodstuffs from which they are produced. Most alcoholic beverages can be broadly classified as fermented beverages, beverages made by the action of

yeast on sugary foodstuffs, or as distilled beverages, beverages whose preparation involves concentrating the ethanol in fermented beverages by distillation. Fermented beverages can be broadly classified by the foodstuff from which they are fermented. Beers are made from cereal grains or other starchy materials, wines and ciders from fruit juices, and meads from honey. Fermented beverages may contain up to 15–20% ethanol by volume, the upper limit being set by the yeast's tolerance for ethanol, or by the amount of sugar in the starting material.

Absolute ethanol and 95% ethanol are themselves good solvents, somewhat less polar than water and used in perfumes, paints and tinctures. Ethanol is used in medical wipes and in most common antibacterial hand sanitizer gels at a concentration of about 62% (Ayele, 2011).

2.11. Application of Bioethanol

- Transportation fuels (Substitution of gasoline)
- Alcoholic beverage (gin, brandy, etc.)
- Feedstock for other chemical industries.
- Diversification of energy sources.
- Enhance energy security.
- Reduction in harmful pollutants from vehicles exhaust.
- Net reduction in lifecycle GHG emissions.

(East African Power Industry Convention 2007, Addis Ababa, Ethiopia)

2.12. Bioethanol Demand in Ethiopia

Ethanol production in Ethiopia is linked with sugar factories and aimed for import substitute of petroleum products, enhance agricultural development and agro processing, job creation, and export earnings.

However, only a small fraction of the potentials is utilized yet, 5% blend has accessed only in the capital city of the country. Moreover, at present only two of the sugar factories, Fincha and Metehara, are producing bioethanol (Gebre egziabher et al., 2014).

Table 2.1 Different source and Feedstock for Bio-Ethanol production and their comparative production potential.

Raw material	Potential of Bio-Ethanol production (liter/ton)
Sugarcane	70
Sugar beet	110
Sweet potato	125
Potato and potato peel	110
Cassava	180
Maize	360
Rice	430
Barley	250
Wheat	340
Sweet sorghum	60
Bagasse and other cellulose biomass	280

Source: Gebreegziabher Z., Mekonnen A., Ferede T., and Köhlin G., 2014. Profitability of biofuels production the case of Ethiopia. Environment for Development Centers.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Equipment Used

Measuring cylinder served to hold solution. Plastic bags to collect and transport samples to the laboratory. Shaker to shake samples and its additives. Fermenter equipment on which chemical change happened due to the action of yeast or bacteria changing sugar to alcohol. Electronic balance to weigh sample. PH meter to measure the PH level of a solution or substance. Spectrometer used to characterize the product. Sieve used to separate fine powder from large particle to >2mm. Miller used to crush the samples to make flour powder. Oven to dry the potato peels. Centrifuge to separate hydrolyte solution from solid sludge by forcing the heavier substance to the outer edge

Test tube to hold sample and cultured bottle. Beaker (1000ml or 500 ml) to hold solution. Magnetic stirrer to stir the solution. Dropper to drop the solution. 1000 – 2000 ml conical flask and shaker incubator.

3.2 chemical used

Table 3.1 Chemical Used

Chemical or material	**Amount used**
Dextrose	9 gram
$Mgso_4.7H_2o$	10 gram
Baking yeast	45 gram
H_2SO_4	1%(v/v%)of diluted sulfuric acid
NaOH	10mole
Urea	9gm

Sulfuric Acid (H2SO4) (98%) is used for pretreatment and hydrolysis of potato peel. Sodium Hydroxide (NaOH) is used to neutralize the pH of soluble sugar before fermentation. Yeast

extracts (Agar), urea, dextrose sugar and Mg SO4.7 H2 used for media preparation. Yeast (Saccharomyces cerevisiae) is used as a nutrient.

3.3. Methods

In this thesis, the method for production of bioethanol from potato peel is diluted sulfuric acid hydrolysis process. This is typically employed when renewable raw material is used as feedstock for bioethanol production. It allows breaking down starch to simple soluble sugar which can be converted to ethanol by fermentation using microbial additive (saccharomyces cerevisae) in the absence of oxygen.

3.4. Process Flow Diagram and Description

The PFD is the general flow sheet of bioethanol production from waste potato peel that includes main process, equipment items, process streams, and utility stream. The stream attribute table is as shown in figure 3.1 below.

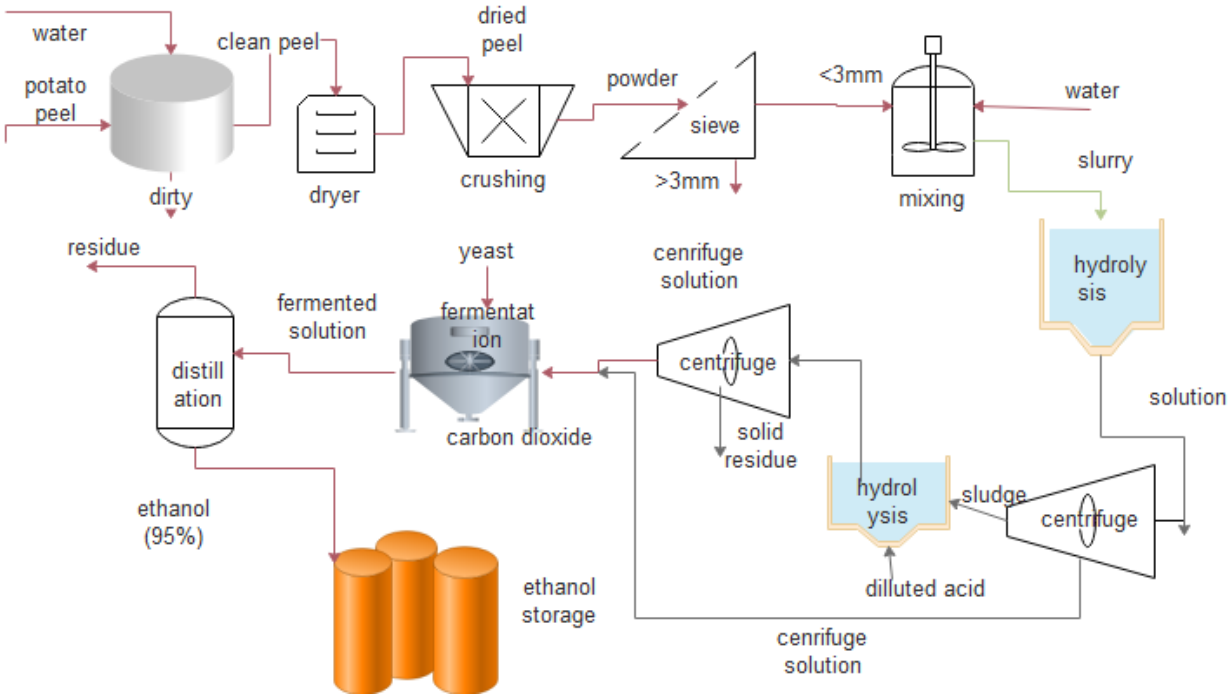


Figure 3.1 flow sheet of bioethanol production

3.4.1. Pretreatment

The pretreatment process involves collection of raw material from source, washing, drying, milling by mortar and sieving it to obtain fine powder. This unit operation prevents the degradation or loss of carbohydrate and byproduct inhibitory to subsequent hydrolysis and fermentation.

3.4.2. Hydrolysis of potato peel

Hydrolysis is the process of breaking down waste potato peel to convert starch of potato peel into fermentable sugars, by using acid hydrolysis process. Biological technologies are used for hydrolysis process. Cellulosic biomass must be pretreated to realize high yields vital to commercial success in biological conversion. Acids have been used to catalyze (speed up) the hydrolysis of starch. There are two basic types of acid processes: dilute acid and concentrated acid, each with variations. Dilute acid processes are conducted under high temperature and pressure, and have reaction times in the range of seconds or minutes while concentrated acid processes conducted under low temperatures and pressures employed allow the use of relatively low cost materials such as fiberglass tanks and piping (Zhu et al., 2008). At temperatures of 50 to 150°C, a process referred to as acid hydrolysis is:

$$(C_6H_{10}O_5)\,n + nH_2O \longrightarrow nC_6H_{12}O_6 \qquad \Delta H = 22.1\text{nkJ/mole}$$

$$(C5H8O4)\,m + mH_2O \longrightarrow mC_5H_{10}O_5 \qquad \Delta H = 79\text{mkJ/mole}$$

3.4.3. Fermentation process

Fermentation is a metabolic process of microorganisms to obtain energy by breaking down organic compound. While microorganisms derive their energy, some by products are lactic acid, butanol, carbon dioxide, ethanol and cellulose. In ethanol fermentation, derivation of energy from sugar by either yeast or bacteria, produce carbon dioxide and ethanol, because yeasts produce energy without need of oxygen. Fermentable sugars consisting of mainly glucose are fermented to get ethanol by using *saccharomyces cerevisiae*. Batch fermentation is carried out in cultured vessels with an initial amount of medium, and fermentation is performed after sterilization of media and adjustment of pH by NaOH. Batch process is the simplest method of fermentation with the simplest control system, in comparison to other modes of operation. Fermentation process is a metabolic process of microorganism which breaks down organic compound by using yeast or bacteria.

$$Glucose \rightarrow 2\ ethanol + 2\ Carbon\ dioxide + energy$$

$$C6H12O6 \rightarrow 2(C2H5OH) + 2(CO2) + energy$$

3.4.4. Simple Distillation

Distillation is a method used to separate two liquid based on the difference of their boiling point. So that distillation is used to separate water and ethanol based on their boiling point. In this experiment simple distillation set up was used at a temperature of 78 ºC for 1:30 hours. The ethanol concentration of the samples was collected on the other end of distillation column to collect the distillate at 78.4^0C (standard temperature for ethanol production). Although the boiling point of bio ethanol is 78.4℃, and that of water is 100℃, we can't get pure bio ethanol by distillation. In order to use bio ethanol as fuel it should be free from water, so dehydration is required to get pure bio ethanol.

3.4.5. Experimental procedure

1. **Sample collection and pre-treatment**

5 Kg of waste potato peel were collected from wolkite university student's cafeteria and washed by 5-liter water to remove dust and debris for 2 hours. The sample was 4.68 kg of cleaned peel after washing. Then dried in oven for 24hr at 103^oC, it was obtained 0.705kg of dry weight potato peel.

The dried peel of potato was ground to fine powder using coffee grinder for 1hr. The grinded sample was sieved to less than 2 mm particle size to obtain fine flour with dry weight of 0.605kg and packed in plastic container until use.



Figure3.2 Collection of potato peel



Figure 3.3Washing potato peel



Figure3.4 Drying in oven





Figure 3.5 Grinding and Sieving

Mixing of Powdered Sample with Distilled Water

225ml of distilled water was added on each of sample of 50gm in 500ml of conical flask at room temperature.

Procedures for Acid Hydrolysis

1liter of 1% (v/v) diluted sulfuric acid was added to the slurry from pretreatment steps in all experiment was run and soaked for 24hr. The solution was then hydrolyzed in the water bath at 94^{o}c.



Figure 3.6 Sample ready to hydrolysis in water batch.

After hydrolysis, the hydrolyte was neutralized with 10 M Na OH until the pH became 6.1.The solid particles was then separated from the liquid in the hydrolyte by centrifugation (to remove the non-fermentable lignin portion).



Figure 3.7 Sample ready for centrifugation.

After separating the solid part, the solid part was washed with distilled water two times. The washing was performed in order to extract all soluble sugars from the solid potato material.

Then the soluble component was mixed with the previously filtered solution from the pretreatment step.

Preparation of Fermentation Media

To prepare 100 ml media, 10gm of Sugar (Dextrose), and 0.2gm of Yeast extract, 1gm of Urea, 100ml of make-up water and 1gm of Mg SO4.7 H2O was mixed together.

Procedures in Media Preparation

To prepare 100ml media, 3gm, 5gm and 7gm of Saccharomyces cerevisiae was added in a 250 ml conical flask according to experimental design. The conical flasks were properly covered, and soaked, then kept for 24hr.



Figure 3.8 Media preparation.

Fermentation

After hydrolysis, the PH of the samples was neutralized with 10 M Na OH until the pH become 6.1. The sample was conditioned to temperature of 30^{o}c. Then the adapted media prepared was added to the soluble sample mix, and then placed in the water bath which contained hot water at 30^{o}c. The prepared solution was fermented for 4, 6 and 8 days.

Distillation

Distillation was the last step in the production of ethanol from potato peel experiments. It is the purifications step. Distillation is the method used to separate two liquid based on their different boiling points. However, to achieve high purity, several distillations are required. In this experiment simple manual distillation were used at temperature of 78.4^{0}c. The distillate for each sample was collected every 1:30 hour. Finally, benzene added to the mixture of 95%ethanol and 5% water to get purified ethanol.



Figure 3.9 Simple distillation on process.

Table 3.1 Adjustment of different parameter for nine experimental run.

Run	Sample amount(g)	Fermentation temp(^{o}C)	Yeast(g)	Fermentation time(day)
Group 1	50	30	3	4
Group 2	50	30	5	4
Group 3	50	30	7	4
Group 4	50	30	3	6
Group 5	50	30	5	6
Group 6	50	30	7	6
Group 7	50	30	3	8
Group 8	50	30	5	8
Group 9	50	30	7	8

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Determination of Yield

4.1.1. Statistical Analysis of the Experimental Results

The process consists of four parts: pretreatment to remove dirt and moisture, reduce the size of starch and increase the porosity of the materials, dilute acid hydrolysis to break down starch to the simple sugar, fermentation to produce ethanol by using yeast and distillation to separate ethanol from water. After following the experimental procedures above, the results for all samples were measured. Ethanol concentration and density measurement of each sample are illustrated by using UV Spectrometer and hydrometer respectively.

A. Moisture content analysis

Mass of entering- mass leaving + generation-consumption = accumulation

Mass of generation = mass of consumption = 0 since during washing there is no reaction.

Therefore, in – out = accumulation

Also accumulation = 0 because at steady state operation

5kg of potato peel collected = 4.68 kg of cleaned potato peel + dirt on potato peel removed

Mass of dirty removed on potato peel = 0.31kg

B. Drying of cleaned potato peel

The moisture content of peel was dried by sun light for one week and in oven at 103^0c for 24 hr.

Cleaned potato peel (4.68kg) = mass of dried sample (0.705kg) + mass of moisture (kg)

Mass of moisture on potato = 3.975kg

From this the total percentage of moisture content on potato peel was calculated as follow

Moisture content = (mass of cleaned potato peel – mass dried potato peel)/mass of cleaned potato = (4.68-0.705)/ (4.68) = 85

=85%

C. Sieving of sample

After crushing the dried potato peel sample weighing 0.705kg by using coffee grinder, sieving was used as separation purpose to make sample particle size about 2mm -3mm. The sample size above 2mm was 0.1 kg therefore the final prepared dry weight of sample potato peel powder was 0.605kg which is obtained after all pretreatment processes.

4.1.2. Characterization of product

4.1.2.1. Density measurement

The density of each run experiment was obtained by using hydrometer equipment. Density measurement has calculated by using pycnometer.

Specific gravity of sample $= \frac{X_2 - X_1}{X_3 - X_1}$

Where, X_1: weight (gm.) of empty pycnometer and X_1= 35

X_2: weight (gm.) of sample+ pycnometer and X_2= 81

X_3: weight (gm.) of sample+ water and X_2= 91

Specific gravity $= \frac{X2 - X1}{X3 - X1}$ = (81-35)/91-35) = 0.8214

Density = specific gravity * density of water =0.8214*1gm/m^3=0.8214gm/m^3

4.1.2.2. Color

The color of bioethanol which produced from potato peel powder is colorless therefore the one thing belongs to ethanol characterization is satisfied.

4.1.2.3. Testing product by chromic acid

This was the second characterization method used. Taking few drops of normal ethanol (which produced in industry) then mixed with few drop of chromic acid, red black color was obtained. The same is true for our sample, taking the similar amount and mixing with the same amount of chromic acid the same color was obtained.

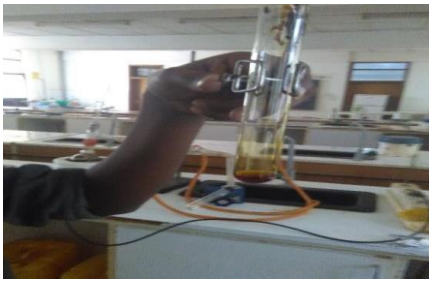


Figure 4.1Testing of ethanol by chromic acid

Table 4.1 Experimental results

Run	Sample amount(g)	Fermentation temperature(C^o)	Yeast(g)	Fermentation time(day)	Bioethanol produced(ml)
Run 1	50	30	3	4	38
Run 2	50	30	5	4	42
Run 3	50	30	7	4	43.2
Run 4	50	30	3	6	45
Run 5	50	30	5	6	50
Run 6	50	30	7	6	48.3
Run 7	50	30	3	8	36
Run 8	50	30	5	8	30
Run 9	50	30	7	8	25

Ethanol Yield (%)

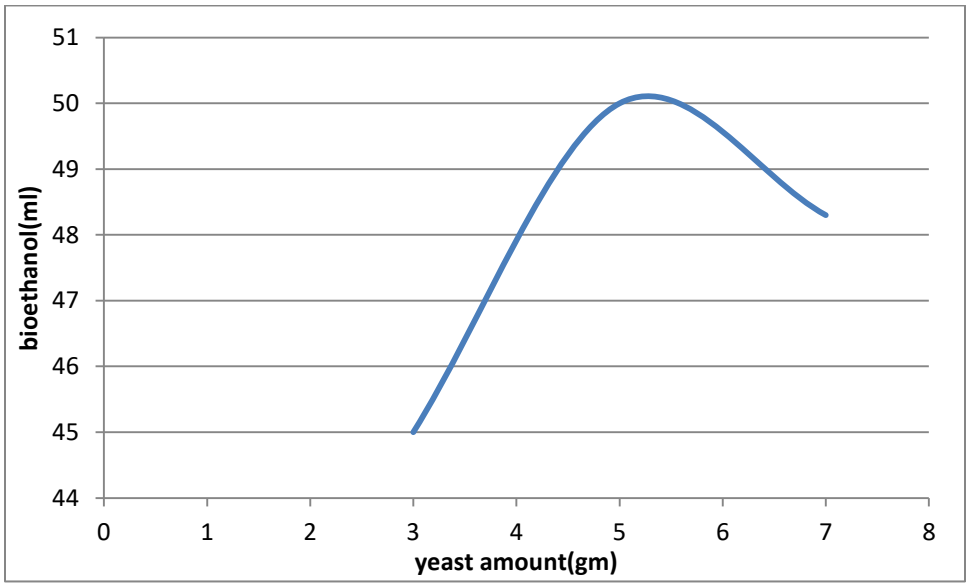
$$Ethanol\ yield(\%) = \frac{mass\ of\ ethanol\ produced}{mass\ of\ dried\ peel\ consumed} * 100\%$$

$$\frac{50ml * 0.8214gm/ml}{50gm} * 100\%$$

= 82.14 %

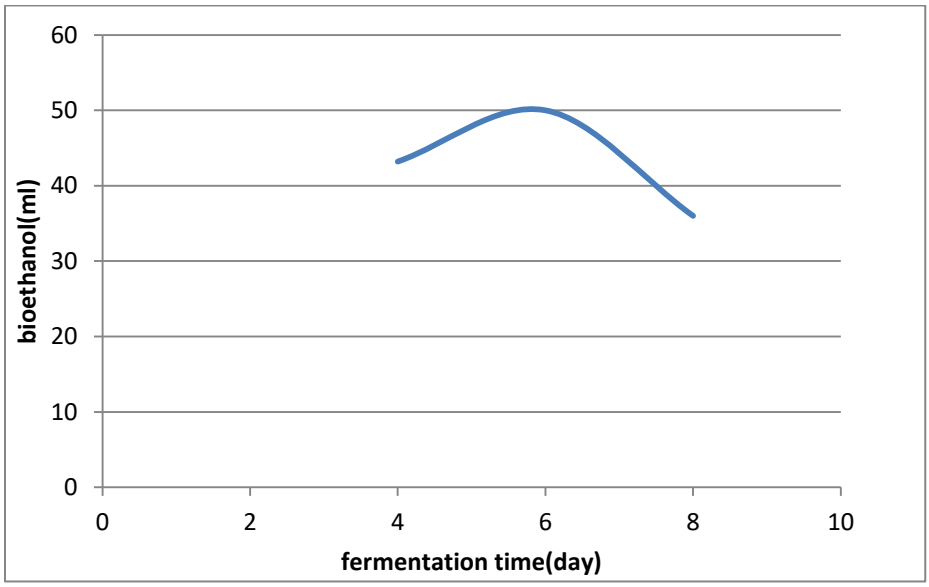
4.2. Effect of Parameter on Ethanol Production

4.2.1. Effect of yeast amount



Yeast is used to facilitate fermentation of potato peel powder as it is used as a nutrient in bioethanol production. Two different amounts of yeast 3gm, 5gm and 7gm were used. The optimum yield was obtained on Run 5 (50ml). As seen from the graph the bioethanol produced increased as the amount of yeast increased, but it is decreased after it reached the optimum amount of the yeast consumed (5gm).

4.2.2. Effect of fermentation time



At fixed temperature fermentation time has an effect on the bio ethanol yield. By varying fermentation time, it was observed that for a long time (6days) the amount of ethanol is higher than that of 4 and 8days. That is might be due to yeast is completely consumed the starch in the long time.

CHAPTER FIVE

5. MATERIAL AND ENERGY BALANCE

The basic principle for both material and energy balance is simply based on the following equation:

Input + Generation = Output + Consumption + Accumulation

5.1. Material Balance

In all the mass balance calculations, no mass accumulation in the design process is assumed. Since the mass balance involved reaction, it is 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 are assumed in equilibrium and the number of moles consumed in the reaction

$\sum$ (Fi) input + $\sum$ (Fi) generated = $\sum$ (Fi) output + $\sum$ (Fi) consumed

5.1.1. Material balance calculation

Plant attainment.

5.1.1.1. Material Balance on Dehydration

Production $= \frac{\text{yield}}{annual}$=$3\times10^6$ lit/yr.

With plant operation day=330/year

In one day =18hr ***orientation***

Anhydrous ethanol (lit/hr.) =$\frac{3000{,}000\ \frac{lit}{yr}}{\frac{330day}{yr}*18hr/day}$

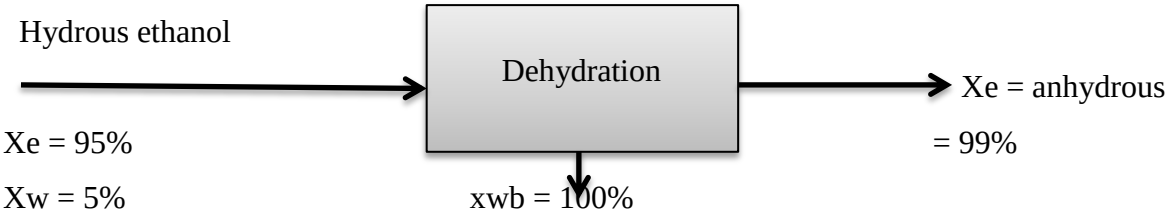
Anhydrous ethanol (lit/hr.) = 505.05lit/hr.

Mass = (505.05lit/hr.*792kg/$m^3\times1m^3$) / (1000lit).

Mass =400kg/hr.

Mass per annual=400kg/hr×18hr/1day×330day/1year=2,376,000 kg/year or 2,376ton/year.

It is equipment which following the distillation column and bring the ethanol concentration from 95% to 99%.



Where X_E=ethanol percentage

X_w=water percentage

Component material balance on dehydration

Input =out put

=0.95×hydrous ethanol (ton/yr.) =99%×2376 ton/yr.

Hydrous ethanol= (0.99×2376ton/yr.)/ (0.95) = 2476.042ton/yr.

- ✓ **The overall material balance on dehydration.**

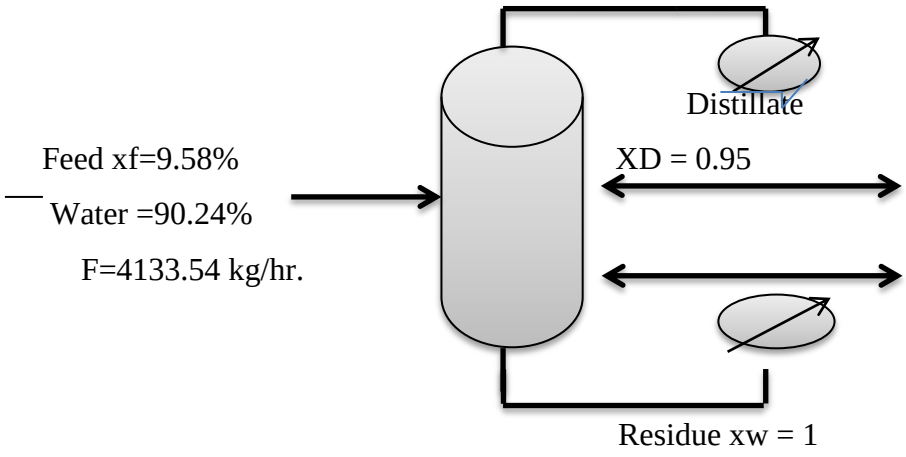
Mass hydrous ethanol=mass water leave + mass anhydrous ethanol

2476.042ton/year=mass water + 2376ton/year

= 100.042ton/year

5.1.1.2. Material Balance on Distillation

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



Where X_{de}=fraction of diluted hydrous ethanol

X_w=fraction of water

Xhe=fraction of hydrous ethanol

From ethanol component balance

$F*X_f=W*Xe+D*Xhe$

F= (2476ton/yr.*0.95)/ (0.0958)=24553.2359ton/yr.

From distillation general material balance;

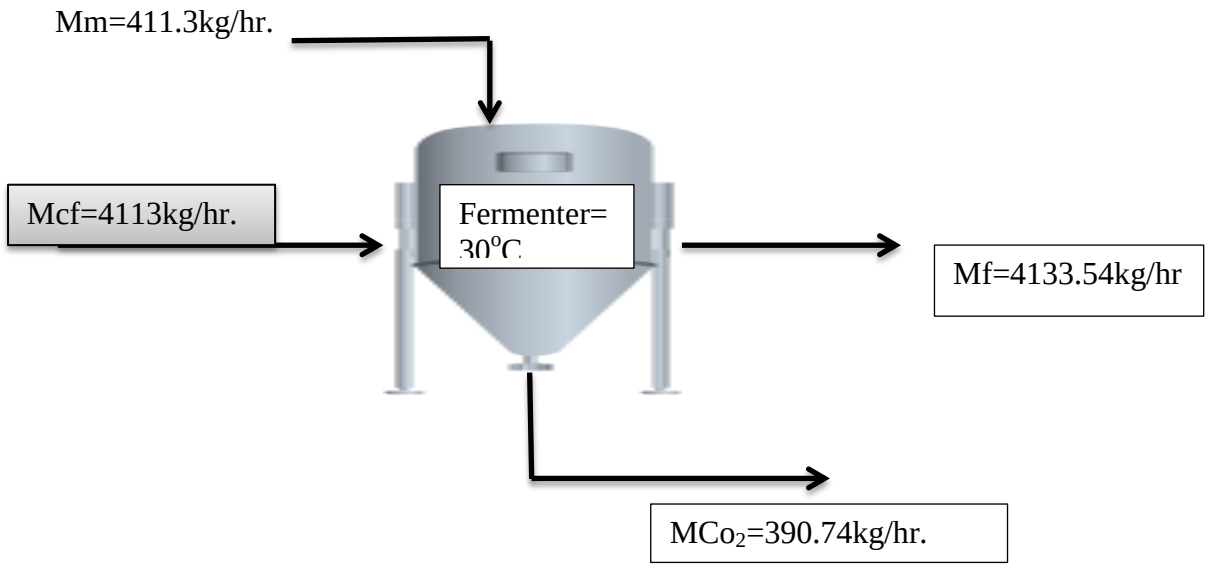
F=W+D

W=F-D =24553.2359ton/yer-2476.042ton/yr.

= 22077.2359ton/yr.

5.1.1.3. Material Balance on Fermenter

Total material balance in fermenter



Where, M_{cf} =mass of centrifuge or filter mash

Mm =media mass

Mf =mass of fermenter mash.

MCO_2 = mass of carbon dioxide

From the reaction of fermentation

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

180gm/mol. $\longrightarrow$ 92gm/mol+80gm/mol.of

CO_2 But (1-3%) of glucose is not changed to ethanol

from literature.

(1%+3%)/2 =2%

Therefore 98% efficiency

Mass of glucose feed/M weight of glucose=mass of hydrated ethanol /molecular weight of ethanol

M glucose/180=2476.042 ton/yr.

Mass of glucose feed =4844.43 ton/yr.× 98% =4747.5 ton/yr.

Mass of carbon dioxide= M_{gf} /180=Mco_2/88

MCO_2=2321.02 ton /yr.

Hence mass of media is 10% of mass of filter mash

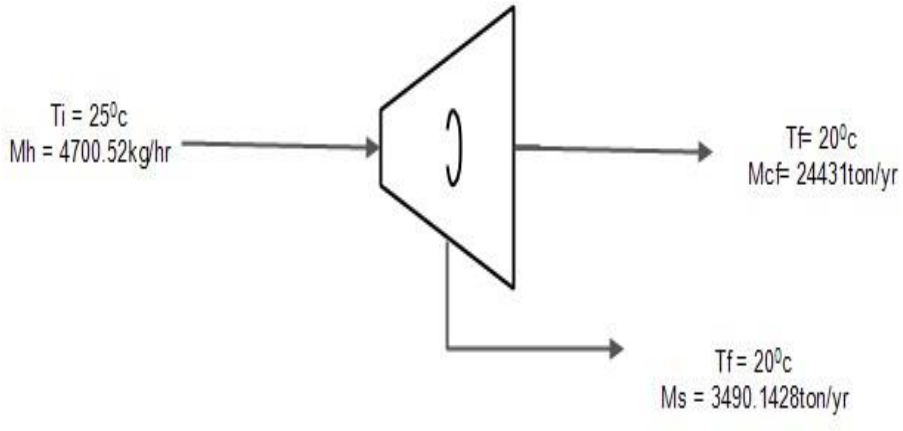
$M_{gf}+M_m=M_f+M\ CO_2$

$1.1M_{cf}=M_f+MCO_2$=24553.35+2321.02/1.1=24431.245

$M_m=0.1\times M_{cf}$=2443.1245 ton/yr.

5.1.1.4. Material Balance on Centrifuge

- ✓ Centrifuge is used for separated insoluble solid from liquid mixture content of centrifuge solid is 20%.



Where, M_h=mass flow rate of acid treated

$M_{s.}$ = mass flow rate of bottom centrifuge solid

M_{cf} = mass flow rate of centrifuge fluid

From the solid component balance

Mh*Xsin =Ms. *Xsout

M_h*0.1=M_s*0.8

From liquid

Mh*Xlin=MsXLout+Mcf*Xlout

Mh*0.9=Ms*0.2+24431*0.1

From the above equation

(Ms*0.8/0.1)*0.9=Ms*0.2+24431 ton /yr.

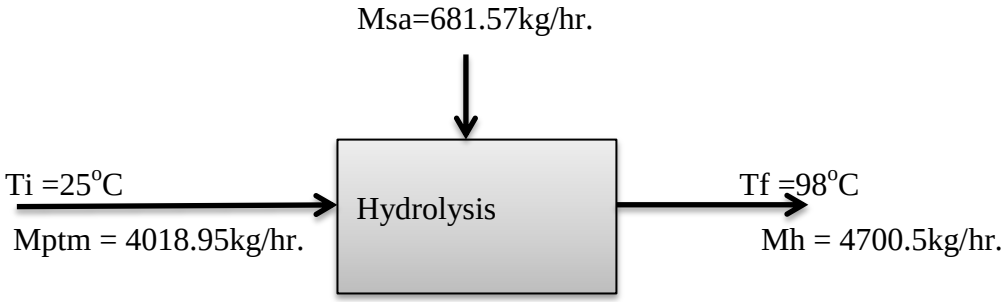
7.2 *Ms -0.2 *Ms=24431ton/yr.

Ms=3490.1428ton/yr.

Mh=Ms*0.8/0.1=3490.1428 ton/yr. *0.8/0.1

Mh=27921.14 ton/yr.

5.1.1.5. Mass Balance on Hydrolysis



Where Mptm =mass flow rate of pretreated mixture.

Msa =mass of diluted sulfuric acid

From the reaction

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

1mol of cellulose $\longrightarrow$ 1 mol of glucose for 100% conversion but not complete conversion and assume that 95% of cellulose convert to glucose.

Mptm/162 = mass of glucose/180 = 27921.14×0.95/180

Mptm = 23872.5747 ton/ year

Applying total mass balance

Mptm+Msa = Mh

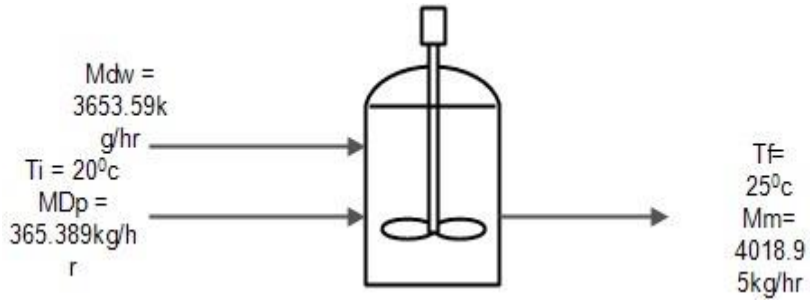
Msa=27921.14-23872.5747=4048.56ton/yr.

✓From the component of mass of sulfuric acid

0.01×4048.56 ton/ yr. = 404856 ton/yr. of sulfuric acid

5.1.1.6. Material Balance on Mixing

It is the equipment used to make homogenous suspension of distilled water and dry potato peel powder.



Where M_{dp} = mass flow rate of dry potato powder

M_{dw} = mass flow rate of distilled water

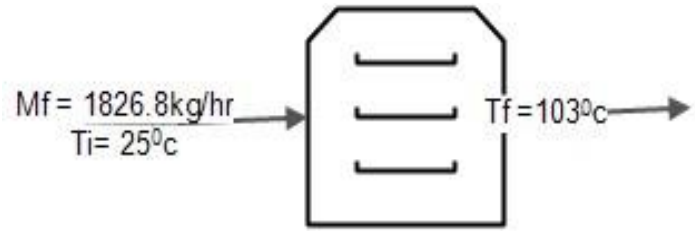
M_{dp} + 10 ×Mdp = Mptm.

M_{dp} = 23872.5747 / 11 = 2170.2340 ton /yr.

M_{dw} = 21702.34 ton /yr.

5.1.1.7. Material Balance on Dryer

It is used to dry the wet potato peel to make agreeable for easily crushing.



Where MFP = mass flow rate of wet potato peel

Mdp = mass flow rate of dry potato peel

XD = fraction of dry powder

Xw = fraction of wet potato peel

Xs= fraction of solid in wet potato peel

✓ Component mass balance for wet potato peel

Mfp*Xs = Mdp*X_d

0.2 * M_{fp} = 2170.234*100%

Mfp = 2170.234×100% / 0.2 = 10851.17 ton/ yr

✓ From over all material balance

✓ Mfp= Mw+ Mdp

Mw = Mfp – Mdp = 10851.17- 2170.234 = 8680.936 ton/ year

Table 5.1 Summary of material balance

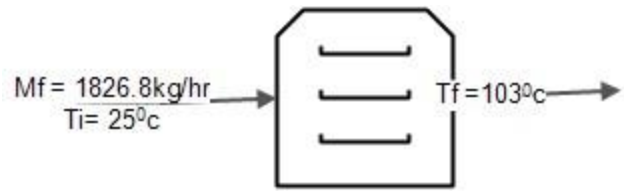
Unit operation	Amount(ton/yr)
Dehydration	2476.042
Distillation	24553.35
Fermentation	24431.245
Centrifugation	27921.14
Hydrolysis	23872.5747
Mixing	2170.2340
Drying	10851.17

5.2. Energy Balance

$$Q + [\sum Fi \int_{TR}^{T} Cpi\, dT]in - [\sum Fi \int_{TR}^{T} Cpi\, dT]out - Fi\Delta Hrx(T) = 0$$

5.2.1. Energy Balance on Dryer

The dryer is dried the sample by 103℃ from 25℃ as initial temperature



$$Q = m \times Cp \times \Delta T$$

$$Where\ m = mass\ of\ peel$$

$$Cp = specific\ heat\ of\ wet\ peel$$

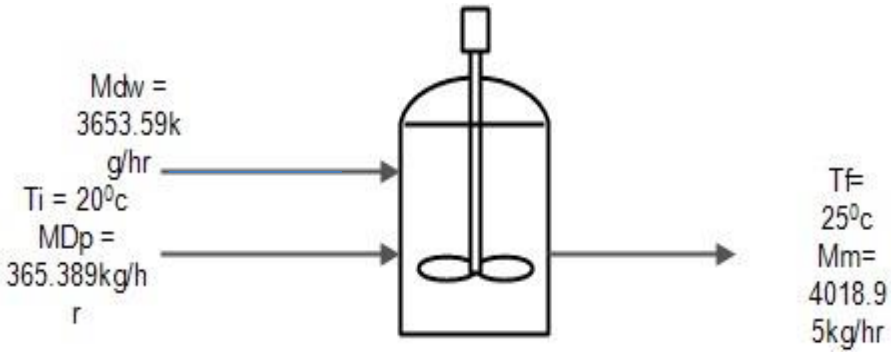
$$\Delta T = Tf - Ti$$

$$Q = 1{,}826.8\ (3.9 \times 0.2 + 4.18 \times 0.8) \times (Tf - Ti)$$

$$= 1826.8 \times (4.124) \times (103 - 25)℃ = 587629.2kj/hr$$

5.2.2. Energy Balance on Mixing

It is the energy used for mix the grained potato peel and distilled water to make suspension.



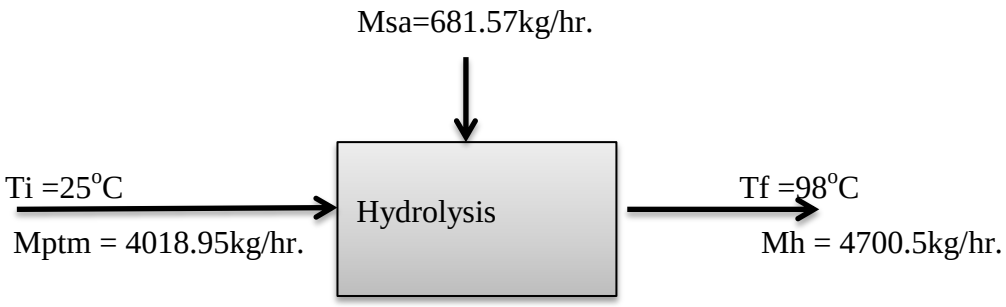
CPm = (365.359kg/hr *3.9+3653.59*4.18)/ (365.359+3653.59)

= (1424.9+15272.0) / (4018.949) = 4.1545kj/kgk

Q = mp * Tm*ΔT* cpm= (4.1545kJ/kgk) * (4018.95kg/hr) * (25-20)

= 83484.5kJ/hr.

5.2.3. Energy Balance on Hydrolysis



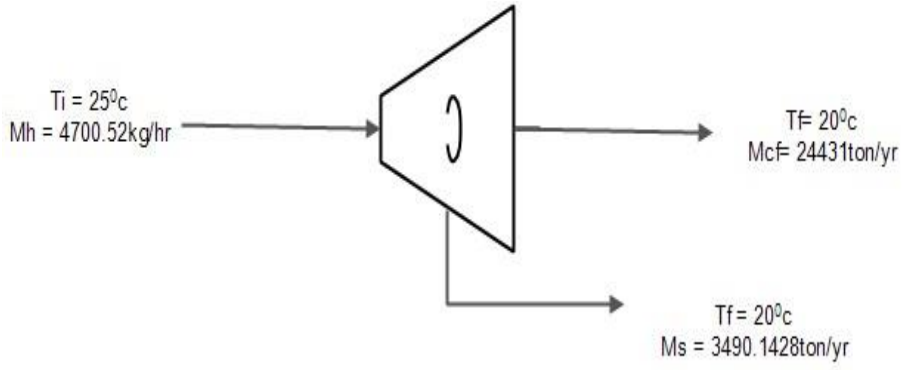
$$Cpmean = (4018.95 \times 3.9 + 681.57 \times 4.18)/(681.57 + 4018.95)$$

$$= (15673.9 + 2848.96)/(4700.5) = 3.94kj/kgk$$

$$Q\ hydrolysis = Mh \times Cp \times \Delta T$$

$$= 4700.525\ kg/hr \times 3.94\ kj/kgk \times (98 - 25).k = 1352168.97\ kj/hr$$

5.2.4. Energy Balance on Centrifuge



Cps = (587.566 × 0.8 × 4.14 + 587.566 × 0.2 × 4.18) /587.566

= (1938.5 + 484.6244) / (587.566) = 4.124kj/hr

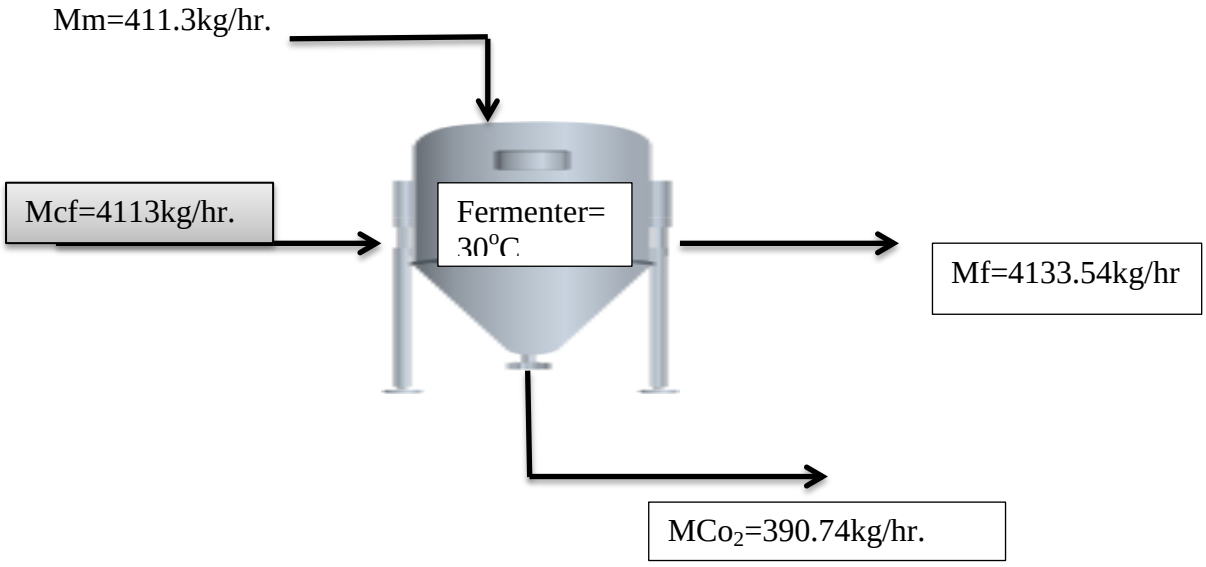
Heat released during the separation can be computed as

$Q = Ms \times Cp \times \Delta T + Mcf \times Cp \times \Delta T$

= 582.566 × 4.124 (25 − 20) ℃ + 4112.96 × 4.18 × 5

= 12115.6 + 85960.864 = 98076.4749kj/hr

5.2.5. Energy Balance on Fermenter



Fermentation is an exothermic reaction heat will be generated inside the fermenter and outlet temperature is 30^{0}°C.

The energy balance on fermenter at 0^{O}C reference temperature

Cp of mix at 30℃ = 4.142kJ/kgk

Cp of co_2 at 30℃ = 0.846kJ/kgk.

$Qmix= Qco_2 + QF + Q$

$Q= Qmix – Qco_2 - QF$

$= Mmix*Cpmix*\Delta T – Mco2*Cpco2*\Delta T – MF*Cpf*\Delta T$

$C_{pf}= Cp\ mix*Xmix+Cpco_2 \times Xco_2$

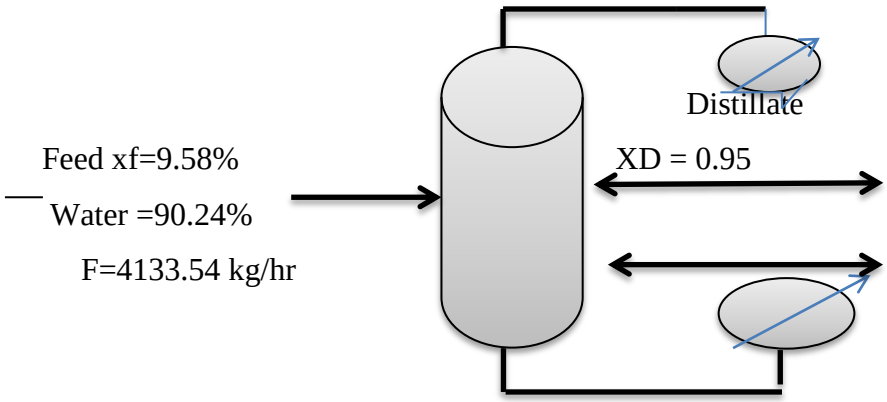
$Xco_2= (Mco_2)/ (M_m + M_{cf}) = 390.74 / (4113+411.3)\ kg/hr= 0.0864$

$X_{mix}= 1- Xco2= 1- 0.0864= 0.9136$

$C_{pf}= 4.142*0.914+ 0.846*0.086= 3.86kj\ /kgk$

$Q= 4524.3*4.142\ (30-0)\ ℃ -390.74*30*0.846-4133\ .54*30*3.86= 5132142kJ\ /hr$

5.2.6 Energy Balance on Distillation Column



✓From the ethanol component balance

$F \times X_f = D \times X_d$

D = (4133.54kg/hr × 0.0958)/0.95 = 416.83kg/hr

W = F – D = (4133.54 – 416.83) kg/hr = 3716.7kg/hr

Heat balance calculation

Basis temperature (25℃)

Heat capacity on the top

Cp distillate = 0.95 × 2.72 + 0.05× 4.18 = 2.793kJ/kg k

Cp on bottom = 4.18kJ/kg k

Balance around the main condenser

Reflux ratio (R) = 2.5

R= L/D = 2.5

L = 2.5 ×D = 2.5 × 416.83 = 1042.075kg/hr

V = L +D = 1042.075 + 416.83 = 1458.905kg/hr

From vapor equilibrium data

Input = output at steady state condition

$H_F = H_d + H_l + Q_c$

$Qc = H_F - H_d - H_l$

Enthalpy of vapor = latent heat of vaporization + sensible heat of vapor

$Hv = mv \times hv + mv \times Cp \times \Delta T$

Hv = (1458.905kg/hr × 789) + (1458.905kg/hr × 2.72*(78.4- 25)℃)

= 1362979.045kJ/hr

Heat balance on re boiler can be calculated as follow

$Q_b + H_F = Qc + H_D + H_w$

$Q_b = Qc + H_d + H_w - H_F$

Heat capacity of feed (H_F) = $M_f \times C_p \times \Delta T$

$H_F = 4133.54 \times 4.04 \times (32-25)℃$

= 116896.5kJ/hr

Heat capacity of bottom (Hw) = $m_w \times C_p \times \Delta T$

= 3716.7kg/hr ×4.18×(100-25)℃

= 1165185.45 kj/hr

$Q_b = Q_c + H_d + H_w - H_f$ hence Hd is zero

Q_b = 1362979.045 + 1165185.45 – 116896.5 kj/hr

= 1181267. 95 kj/hr

From steam table data the latent heat of steam equal to 2174kj/kg

M_s (steam required) = Q_b/h_s = 1181267.95/2174

= 543.36kg/hr

5.2.7. Energy Balance on Dehydration

Hydrous ethanol

Xe = 95%

Xw = 5%

xwb = 100%

Xe = anhydrous

= 99%

$$Cp = Cpet \times Xet + Cpw \times Xw = 2.72 \times 0.95 + 0.05 \times 4.18$$

$$= 2.79\ kj/kg\ k$$

$$Q = methanol \times Cp \times \Delta T$$

$$= 400kg/hr \times 2.79\ kj/kg\ k \times (95 - 25) = 78120\ kj/hr$$

Table 5.2 Summary of energy balance

Unit operation	Energy required (kJ/hr)
Dryer	587629.2
Mixing	83484.5
Hydrolysis	1352168.97
Centrifuge	98076.475
Fermenter	5132142
Distillation	1165185.45
Dehydration	78120

CHAPTER SIX

6. COSTING AND ECONOMICAL FEASIBILITY

The aim of this section is to present information regarding the economic feasibility for the production of bioethanol from potato peel. The technical feasibility and the process routes have been established and outlined in the previous sections. For the purpose of this economic study, the mass balance information presented in the above section has been used. This economic evaluation is based on the utilization of 7200 kg of potato peel per day. The costing for this study is based on the determination of percentage of delivered equipment cost estimation, which is commonly used for preliminary and study estimates. The complete cost estimation of the plant is included into two main parts—total capital investment and production cost.

Basis of economic analysis:

- Start of construction: January, 2022
- Completion of construction: January 2024
- Commencement of processing: May 2024
- Plant operation: 18 hours / day
- Processing mode: - batch process.
- Plant life: 15years (Peters et al,1986)
- Plant production rate: 2376 ton/year.
- Working period: 330 days.
- Selling price of product =10birr/liter.

6.1 Total Capital Investment

Before a plant can be put into operation, a large sum of money must be supplied to purchase and install the necessary machinery and equipment. Land costs and service facilities must be obtained, and the plant must be erected complete with all piping, controls, and services. In addition, it is necessary to have money available for the payment of expenses involved in the plant operation. The capital needed to supply the necessary manufacturing and plant facilities is called the fixed capital investment and includes direct and indirect costs, while that necessary for the operation of the plant, in the initial phase, is termed the working capital. The sum of the fixed capital investment and the working capital is known as the total capital investment. The total

capital investment is determined by percentage of delivered equipment cost estimation in this report.

Table 6.1 Chemical Engineering Plant Cost Index

Year	2009	2010	2011	2014	2016	2017	2018	2020	2021
CEPCI	525.4	575.4	521.9	550.8	585.7	690.4	760.2	795.4	812.99

*The index for 2021 is determined by extrapolation

2018= 760.2

2020= 795.4

2021=x

(2020-2018) / (795.4-760.2) = (2021-2020)/(X-795.4), X = 812.99

A. Fixed Capital Investment (FCI)

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

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

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

Table 6.2 Purchased equipment cost

Types of equipment	Quantity	Capacity	Cost In ($)
Raw material storage	1	0.473m3	2466.54
Media storage tank	1		6500
Pretreatment tank	1	5.3m3	8274.56
Acid treated tank	1	0.63m3	8582.10
Mixer tank	2	5.3375m3	3000
Dryer	1	1826.76kg/hr	5000
Fermented storage tank	1	5.45 m3	8413.04
Fermentation tank	10	100.73 m3	25000
Centrifugal separation	5	4700.5kg/hr	12500
Grinding	1		2000
Distillation	1	4133.56kg/hr	6894.95
Sieve	1		1103.62
Ethanol storage tank	1	400kg/hr	2988.0045
Boiler	1	328.12kw	7500
Condenser	1	378.6kw	8000
Filter	1	416.84kg/hr	6000
Water storage tank	1	100.5kg/hr	8168.94

From purchase equipment cost we can determine initial fixed capital investment. I.e. Purchased equipment cost (PIC) = (15-40 %) fixed capital investment (FCI).by Choosing average value 27.5% in our project.

PIC=27.5%FCI

FCI=PIC/0.275= $365005.759/0.275 = $1327293.67

Cost equipment TFCI for 2017= FCI 2014*(cost index2017/cost index2014)

1327293.69*795.4/690.4 = $1529156.12

I. The direct fixed capital investment

The direct-cost items that are incurred in the construction of a plant, in addition to the cost of the equipment items are:

1. Purchased-equipment erection, installation;
2. Piping
3. Electrical equipment and materials, power and lighting;
4. Instrumentation and controls;
5. Process buildings and structures;
6. Yard improvements;
7. Service facilities;
8. Land;

Table 6.3 the direct-cost items that are incurred in the construction of a plant

Direct cost	Percentage (%)		cost in $
Purchased equipment cost	15-40%FCI	27.5%FCI	420,517.933
Installation Cost	6- 14%FCI	10%FCI	152,915.612
Instrumentation and Control Cost	2-8%FCI	5%FCI	76,457.806
Piping Cost	3-20%FCI	10%FCI	152,915.612
Cost of Electrical Systems	2-10%FCI	6%FCI	91749.367
Cost of Buildings and Structures	3-18%FCI	10%FCI	152,915.612
Cost of Yard Improvement	2-5%FCI	3%FCI	45874.6836
Service Facility and Utility Cost	8-20%FCI	12%FCI	183498.734
Cost of Land	1-2%FCI	1.5%FCI	22937.34
		Total	1,299,782.7

II. **The indirect fixed capital investment.**

In addition to the direct capital investment, the capital investment of a project will include the indirect capital investment of the process plant. The indirect-cost items that are incurred in the construction of a plant are: engineering and supervision construction expense contractor's fee and Contingency.

Table 6.4 Indirect capital investment calculation

Engineering and supervision	4-21%FCI	12.5%FCI	191144.515
Construction expense	4-16%FCI	10%FCI	152915.612
Contractor's fee	2-6%FCI	4%FCI	61166.2448
Contingency	5-15%FCI	10%FCI	152915.612
		Total	458,141.984

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

- ✓ Start up
- ✓ Raw material and supplies carried in stock
- ✓ Finished and semi-finished products in stock
- ✓ Accounts receivable and payable

Cash kept on hand for monthly payment of operating expenses and Taxes payable. It is estimated that working capital is approximately 15% of total capital investment.

Costs summary of total capital investment.

By adding the direct plant cost, indirect plant cost and working capital, the total investment required can be estimated. The total capital investment for this project is:

$$Total\ Capital\ Investment\ (TCI)$$

$$= Total\ fixed\ capital\ investment + Working\ capital\ (WC)$$

$Total$ fixed capital investment =TDC+TIDC= 1,757,924.68

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

Thus, Total capital investment (TCI) $\$ = 0.15\text{TCI} + \text{FCI}$

TCI-0.15TCI= FCI but FCI= 0.85TCI

TCI=FCI/0.85= 1,757,924.68/0.85 = $2,068,146.68

6.2. Estimation of Total Production Cost

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

1. **Manufacturing Costs**

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

(1) Direct production costs,

(2) Fixed charges, and

(3) plant-overhead costs

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

❖Direct production cost calculation

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

1. Raw materials (l0-50% of total product cost)
2. Operating labor (10-20% of total product cost)
3. Direct supervisory and clerical labor (10 -25% of operating labor).
4. Utilities (10-20% of total product cost).
5. Maintenance and repairs (2-10% of fixed -capital investment)
6. Operating supplies (10 -20% of cost for maintenance and repairs, or 0.5-1% of fixed capital investment).
7. Laboratory charges (10-20% of operating labor).
8. Patents and royalties (0-6% of total product cost)
9. Raw material (10 -40%) 0f total production cost.

Operating labor

The total human resource requirement of the plant will be 66 persons. The total annual cost of human resource is estimated at $83,932.144. Details of human resource and salaries are presented in the following table.

Table 6.5 Operating Labor cost summary

R.No	Description	No. of Persons	Monthly(birr) Salary for one persons	Total salary	Annual Salary(birr)
1	General Manager	1	12000	12000	144000
2	Finance Manager	1	7,000	7,000	84,000
3	Technical Manager	1	6500	6500	78000
4	Commercial manager	1	8000	8000	96000
5	Accountants	2	3,600	7200	86400
6	Sales/Purchase	2	2000	4000	48000
7	Store keeper	2	1700	3,400	40,800
8	Secretary	1	1,400	1400	16800
9	Production Manager	1	8600	8600	103200
10	Operators	14	3,000	4200	504000
11	Mechanic	2	3000	6000	72000
12	Electrician and instrument	3	2,000	6,000	72,000
13	Production supervisors	3	2,600	7,800	93,600
14	Assistant operators	10	2,000	20,000	240,000
15	Unskilled workers	11	900	9900	118,800
16	Time keeper	3	1,000	3,000	36,000
17	Messenger and cleaner	4	800	3,200	38,400
18	Guard	4	1,200	4,800	57,600

$$\text{Operating labor} = 1{,}929{,}600 \text{ birr} X \frac{1\$}{22.99 birr} = \$\ 83932.144$$

$$\text{TPC} = \text{operating}\frac{\text{labor}}{15}\% = \frac{\$}{0.15} = \$\ 559547.629$$

Raw material cost = 0.1 $X^{559,547.629}$

= $55954.7629

I. Direct supervisory and clerical labor

Direct supervisory and clerical labor is taken as 10-25 % of operational labor. For this project we take 17.5 %.i.e. Direct supervisory and clerical labor=17.5% of operating labor

$0.175 \times \$\ 83932.144 = \$14688.1252$

III. Utilities

This will include the cost of electricity, process cooling water, and other forms of utility that is required to keep the plant in operation. This is Utilities (10-20% of total product cost).It taken the Average value.

$$15\%\text{TPC} = 0.15 \times 559547.629 = \$83932.144$$

IV. Maintenance and repairs

If a plant is to be kept in efficient operating condition, a considerable amount of expenses is necessary for maintenance and repairs. Maintenance and repairs= (**2-10%** of fixed -capital investment)

6%FCI= 0.06×1,757,924.68 = $105,475.481

V. Operating supplies

This includes the cost of items such as lubricants; test chemicals, charts etc., and required to keep the plant functioning efficiently. Operating supplies= (**10 -20%** of cost for maintenance.

$$= 15\% \times 105{,}475.481 = \$15{,}821.3222$$

V. Laboratory Charges

This involves cost of laboratory tests for control operation and product quality control. It is taken as 10-20% of operating labor.

$15\% \times\ 83932.144\ = \$12589.82$

VI. Patent and royalties

It is taken as 0- 6% of total production cost. Take 3%of TPC

3%×559547.629= $16786.4289

Direct production cost = $389,180.327

Fixed charges

Fixed charges Costs that are invariant with the amount of production

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

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

2. Local taxes (1-4% of fixed-capital investment).

3. Insurance (0.4-1% of fixed capital investment)

- Depreciation= $(0.1 \times 1{,}757{,}924.68 = \$175{,}792.468$
- Local taxes $= 0.025 \times 1{,}757{,}924.68 = \$43{,}948.117$
- Insurance $= 0.007 \times 1{,}757{,}924.68 = \$12{,}305.4728$

Total fixed charges = $232,046.058

❖ **Plant-overhead costs**

(50-70% of cost for operating labor. **)**

Take 60% of opl = 0.6×83932.144 = $50,359.2864

Total manufacturing cost = $368,273.907

Total manufacturing cost = Fc + plant overhead cost + direct production cost

TMC = 232,046.58 + 368,273.907 + 389,180.327 = $ 989,500.292

❖ **Estimation of general expenses**

- General expense

$$= \text{administrative } costs + distribution\ and\ selling\ costs + research\ and\ development\ costs + financing \text{ expenses}$$

a) Administrative costs (about 15% of costs for operating labor, supervision, and maintenance.

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

c) Research and development costs about 5% of total product cost).

- Administrative costs = $0.15 \times (31637.6 + 14688.1252 + 83932.144)$= $19,538.68
- Distribution and selling costs=0.11×559547.629 = $61550.239
- Research and development costs=0.05×559547.629 = $ 27977.38

So, general expense =19,538.68+61,550.239+27977.38 = $ 109,066.299

TPC = DC+FCC+POH+GEC = manufacturing cost + general expense cost

TPC = 989,500.293 + 109,066.299 = $1098566.59

Depreciation of plant equipment Assumption

The useful life of all the machines is 15 years (that is after it exceeds its salvage value, but it is still useful and effective) and the salvage value of each of the machine is assumed to be 20% of the cost price of the machines.

Equipment depreciation cost estimation

Table 6.6 Operating Labor cost summary

List of equipment	Purchased cost, in $	Salvage value 25% of initial cost of equipment, $	Depreciable value, $
Raw material storage	2466.54	616.635	1849.905
Media tank	6500	1,625	4,875
Pretreatment	8274.56	2068.64	6205.92
Acid treated	8582.10	2145.525	6436.575
Mixer	3000	750	2250
Dryer	5000	1250	3750
Fermentation tank	25000	6250	18750
Fermented tank	18413.04	4603.26	13809.78
Ethanol storage	2988.045	747.01125	2241.033
Distillation	6894.95	1723.7375	5171.21
Centrifuge	12500	3125	9375
Grinding	2000	500	1500
Sieve	1103.62	275.905	827.7
Boiler	7500	1875	5625
Condenser	8000	2000	6000
Filter	6000	1500	4500
Water tank	8168.94	2042.235	6126.705

Total depreciable cost = $ 108,574.535

6.3. Financial Evaluation

6.3.1. Profitability

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

➢ **Break-even Analysis**

The break-even analysis establishes a relationship between operation costs and revenues. It indicates the level at which costs and revenue are in equilibrium.

➢ **Pay-back Period**

The pay -back period, also called pay – off period is defined as the period required for recovering the original investment outlay through the accumulated net cash flows earned by the project. Accordingly, based on the projected cash flow it is estimated that the project's initial investment will be fully recovered within years.

Revenues for the bio ethanol production process

The revenues of the ethanol production process options mainly come from the direct sales of bio ethanol. Based on the usage of 9090.909 liter of ethanol per day.

Selling Price

Total income = selling price of product × production capacity

Total income of ethanol selling =10birr/lit*(1$)/45.98birr.*3,000,000lit/year= 1304915.19$/year

Table 6.7 Annual sales revenues

Types of product	Amount produced /day	Amount produced /year	Cost of product in dollar	Total cost of the products in $
Bioethanol	9090.90 lit/day	3000000 lit/year	12birr/lit $\frac{1\$}{44.98 birr}$	$1,565,898.21
Animal feedstock	10.576 ton/day	3490.1428ton/year	30birr/ton	$4554.34
			Total	$1,570,452.55

❖ **Simple estimate on return on investment (ROI)**

Before performing the detailed economic evaluation, a simple return on investment ROI is calculated as a measure of annual rate of return on capital employed in production and optimization of bioethanol from potato waste. In engineering economic evaluation, it is usually defined as the percent ratio of average yearly profit (net cash inflow) over the productive life of the project, divided by total initial investment. A positive ROI means the annual revenue is larger than the production cost; in other word, the plant is profitable.

$$\text{ROI} = \frac{\text{annual profit}}{\text{total capital investment}} * 100\%$$

Calculation

Total income = $1,570,452.55

Total Expense = TPC= $1,098,566.59

Gross profit: $\text{Gross profit} = \text{Total income} - \text{expenses}$

= 1,570,452.55 – 1,098,566.59

= $ 471,885.98/year

Profit tax = 34% X 471,885.98 = $160,441.233

Net profit after tax = net profit before tax – profit tax

= 471,885.98 – 160,441.233 = $311,444.75

a) Before tax

$$\text{ROR} = \frac{\text{NET PROFIT}}{\text{TCI}} \times 100\% = \frac{471,885.98}{2,068,146.68} \text{ X } 100\% =$$

22.8%

b) After tax

$$\text{ROR} = \frac{\text{NET PROFIT AFTER TAX}}{\text{TCI}} 100\% = \frac{311,444.75}{2,068,146.68} \text{ X } 100\% = 15.055\%$$

Pay Out Period

$$\text{Pay out period} = \frac{\text{FCI}}{\text{net profite+deprciation}} = 1,\ 757924.68/\ (108,574.535 + 471,885.98)$$

= 1757924.68/580,460.515 = 2.89 years

❖ Break-even Analysis = $\frac{\text{FCI}}{\text{TPC}-\text{WCI}} = \frac{1757924.68}{1{,}098{,}566.59-310222.002} = 2.22989$

Table 6.8 General cost summery

Fixed capital investment(FCI)	$1,757,924.68
Working capital(WC)	$788,344.59
Total capital investment(TCI)	2,068,146.68
Total production cost(TPC)	1,098,566.59
	108,574.535
Total income	1,570,452.55
Gross profit	471,885.98
Net profit	311,444.75
Rate of return(ROR) before tax	22.8%
Rate of return(ROR)after tax	15.055%
Payback period	2.89 year
Breakeven point	2.22989

CHAPTER SEVEN

7. PLANT SITING, LAYOUT AND LOCATION

7.1. Plant Location

The geographical location of the plant has a strong influence on the success or failure of the plant. Therefore, it has a crucial effect on the profitability of the plant, and the scope of future expansion work. Therefore, a plant should be located where minimum cost of production, as well as distribution of product to selling could be obtained, amongst other factors.

7.1.1. Plant Location

In order to make the design project realistic, the aspect of site selection must be given some consideration. There are a number of considerations concerning the choice of site and location for bioethanol production plant. Some general considerations are

- Climatic condition
- Proximity to both the raw materials supply and the market for the product selling.
- Political and strategic considerations.
- Location community considerations.
- Availability of suitable land etc.
- Proximity to major transportation networks e.g. roads, railways.
- Designation as a heavy industrial development area.
- Prior existence of similar chemical plants and location of other industrial centers
- Existing roads and services and also appropriate terrain, sub surface, drainage etc.
- Suitable access for transportation for transportation of raw materials and chemicals and for
- Construction of a chemical plant.
- Availability of a local workforce and distance from local communities.
- Environmental discharge regulation and cost of land and services

7.1.2. Availability of Raw Material

The main raw materials availability for bioethanol production from potato peel is highly available in wolkite. It is Looking at the probable site location, because wolkite and place around wolkite produce a high level of potato peel which is obtained from different area such as cafeteria , hotel and wolkite university student cafeteria so generally wolkite good place of main raw material for the production of bioethanol from potato waste.

7.1.3. Availability of Suitable land

The suitability of land is judged based on some factors including: drainage, load bearing characteristics and flatness. The sites must therefore be evaluated to determine the need for any special foundations based on those criteria wolkite is better than other place of Ethiopia.

7.1.4. Utilities.

Utility availability is crucial for plant to success such as water, electric and labor availability. Those sources are available in wolkite.

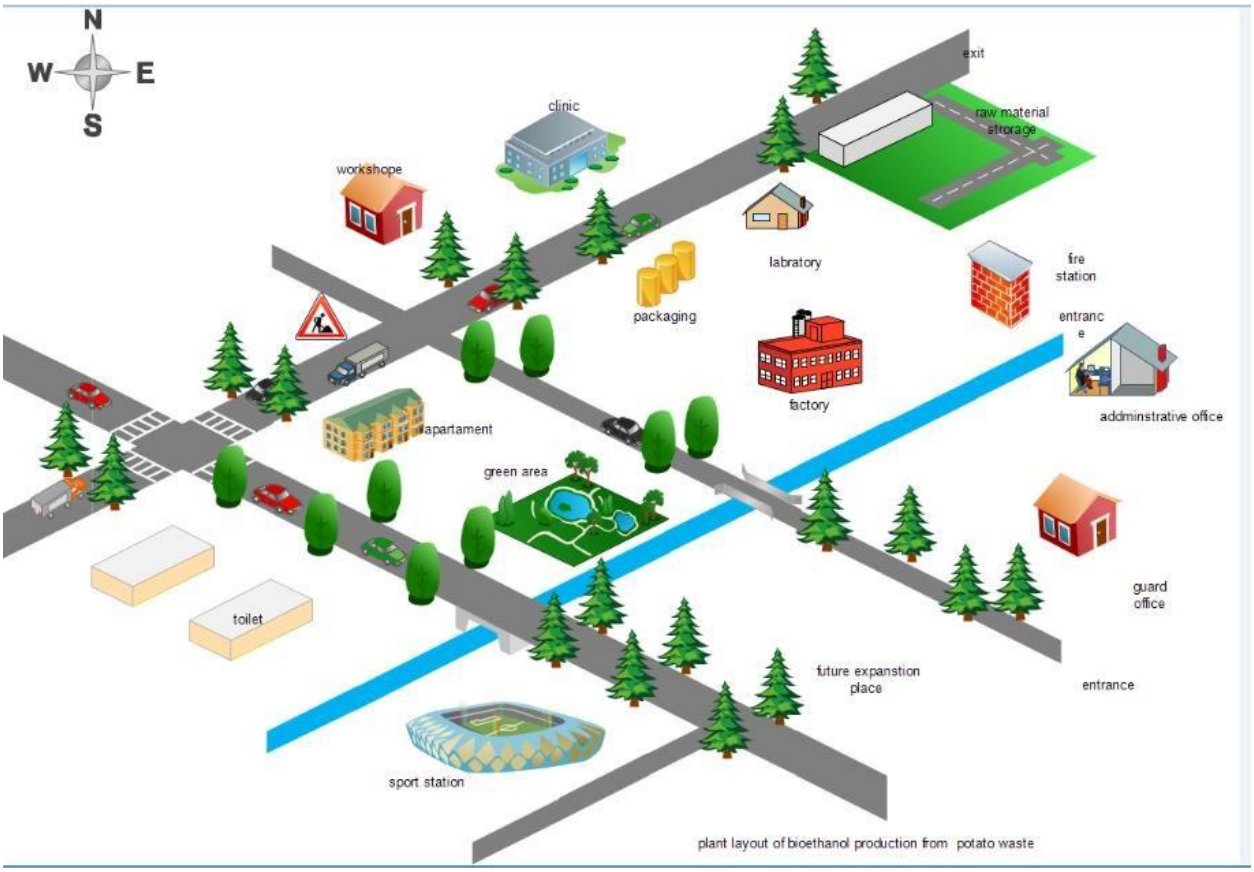


Figure 7.1 Figure: Plant Layout

CHAPTER EIGHT

8. CONCLUSION AND RECOMMENDATION

8.1. Conclusion

In this research ethanol was produced from wastes generated from potatoes. Starch hydrolysis with dilute acid was carried out. The effect of yeast amount and fermentation time on fermentation of potato peels was investigated. From experimental results, all the process variables have significant interaction effect on bioethanol production. The maximum value of the yeast amount and fermentation time contributed negative effect on bioethanol. The optimal value of these two factors 5gm for yeast and 6 days fermentation time. Generally waste potato and potato peel was found as a promising carbon source for bioethanol production using an alternative method and relatively inexpensive compared with other feedstock or sources.

8.2. Recommendation

This research would like to suggest the following recommendation.

Works done with regard to bioethanol production should not remain on paper and they should be implemented.

The government should involve on bioethanol production from wastes generated from household, restaurant, hotels, cafeterias and chips shops to encourage business owners.

Dilute acid was used for hydrolysis of starch in this experiment; however hydrolysis with microorganism has to be checked.

Most of the solid wastes including peel waste in our country have no or very low conversion to different usable products and as such among the major problems of health especially for cities. Hence, it recommended that government or other investors to recover this very valuable product as well as to contribute to the country in reducing the highly rising quantity of wastes. By widening the scope of the project one can add the detail design of the production equipment and the economic analysis for the project.

The economic analysis was done based on a rough estimation of equipment cost; but a detail cost analysis of each material and utilities to be used in the construction should be obtained for better economic analysis. Detailed economic data are necessary for a more accurate economic analysis. It is recommended that information about the cost of all components of the plant for different capacities should be collected.

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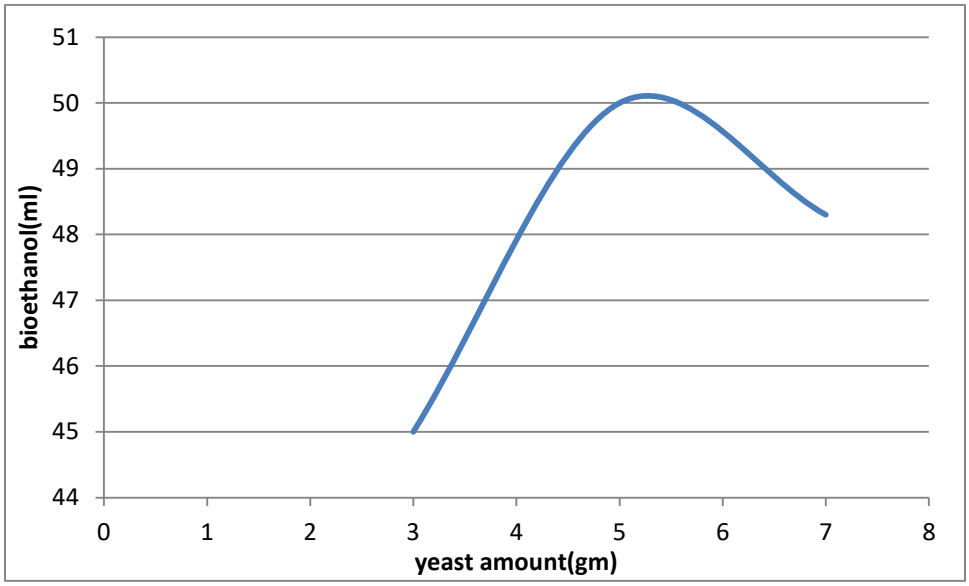
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APPENDICES

1. characterization of bioethanol

Run	Sample amount(g)	Fermentation temperature(C^o)	Yeast(g)	Fermentation time(day)	Bioethanol produced(ml)
Run 1	50	30	3	4	38
Run 2	50	30	5	4	42
Run 3	50	30	7	4	43.2
Run 4	50	30	3	6	45
Run 5	50	30	5	6	50
Run 6	50	30	7	6	48.3
Run 7	50	30	3	8	36
Run 8	50	30	5	8	30
Run 9	50	30	7	8	25


51
50
49
48
47
46
45
44
bioethanol(ml)
0
1
2
3
4
5
6
7
8
yeast amount(gm)