ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

PRODUCTION OF BIO-FUEL & BIO-PLASTIC FROM VEGETABLE WASTE AS A SUSTAINABLE WASTE MANAGEMENT

B.Sc. Engineering (Mechanical) THESIS

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DECLARATION

It is hereby declared that, their thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

Enlargement of different sectors like industrial, automobile etc. Depends upon the progressive demand of petroleum. Most of the petroleum are commonly known as Hydrocarbon. In Bangladesh, a huge amount of fuel needs to run these sectors, which are imported from overseas. Increasing the supply of fuel is a crying need now-a-days in Bangladesh. Due to economic, social and ecological reasons, several studies have been done in order to obtain alternative fuel sources. In this respect, fermentation, trans-esterification, pyrolysis of biomass, industrial, domestic waste and vegetable waste have been proposed as alternative solution for increasing the energy demand and environmental awareness. Among these different approaches, pyrolysis seems to be a simple and efficient method of fuel production. Bangladesh produces a huge amount of vegetables every year. A certain amount of vegetables are damaged due to bacteria, virus or transporting these from one place to another. Different types of ingredients can be decomposed from these vegetables by pyrolysis system. These ingredients are essential for different reactions to produce biofuels. Vegetable waste to biofuel production is a good way of sustainable waste management, which can also meet the demand of fuels in Bangladesh. For different types of industrial machineries, transports and gasoline enhancer, biofuels from vegetable waste can be used. A huge amount of currency can be saved if biofuel production will be industrialized in Bangladesh.

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INTRODUCTION

All different forms of energy are vital to humanity and is central to the development in people's quality of life. Global energy demand is increasing day by day though the environmental quality is getting worse. In the 21st century, while the demand for energy for transportation, heating, and industrial processing is increasing day by day, environmental issues are a point of concern (Hahn-Hagerdal et al. 2006). Biofuels recently became more attractive to people because of their environmental benefits and due to the uncertainties concerning petroleum availability as bio fuels are renewable source of energy (Demirbaş, A. 2003). According to the Energy Information Administration (EIA, 2008a), the U.S. is the major consumer of oil, consuming 20.7 millions of barrels per day in 2007. Renewable energy sources receive attention not only to protect the environment, but also to supply energy needs by reducing dependence on foreign oil. In recent years, bioenergy sources have become more important as a viable and economical alternative source.

Bio-ethanol is ethanol fermented from renewable resources such as crops or lingo-cellulosic biomass is used as fuel (Grassi, G. 1999). It is one of the bioenergy sources with high efficiency and low environmental impact. Worldwide production of ethanol is approximately 51,000 million liters. Fuel encompassed 73% of produced ethanol, while beverage and industrial ethanol constitute 17% and 10%, respectively (Sanchez and Cardona, 2008). As a fuel enhancer, ethanol has some advantages. Bio-fuels, particularly bio-ethanol is getting much attention as an option for renewable transport fuel. Countries having tropical weather condition have successfully utilized potatoes for decades to produce ethanol (Wheals, A. 1999). Everyday food and agricultural wastes are produced. They are contributing to the increase of carbon footprint as they are getting disposed in the environment regularly. According to the Food and Agriculture Organization this is critically affecting climate change and environmental pollution in the world (Ali Mekouar, M. 2011). Food wastes from local and large supermarkets and retail stores are also contributing in this regard (Eriksson, M. And Spångberg, J. 2017). Bangladesh imports most of the oil from Middle East, which is costly as we are spending lots of foreign currency. This need for oil is on the rise due to infrastructure development of the country. Price of oil is also increasing because of the unrest global political problems. This huge spend on oil import has created enormous pressure on Bangladesh's annual budget. However, it can be easily solved by using renewable sources of fuels which is cheap and not that much harmful for environment. Because of its geographical position Bangladesh is hugely depended on agriculture and the lands are very fertile. Bangladesh produces a huge amount of potatoes and sweet potatoes and other vegetable most of them are lingo-cellulosic and can be used as the promising source of bioethanol (Azad, A., Yesmin 2014). As huge number of vegetables are getting wasted every year those can be used to produce bio-ethanol to use for the production of bio-fuel. This will also help the farmers financially as poor farmers can earn from selling rotten vegetables. Root level production can also be introduced if possible. This will Bangladesh both economically and environmentally.

To reduce the use of fossil fuels, decrease the emission of carbon dioxide, and reduce dependency on foreign oils, ethanol is an alternative bioenergy source. Since ethanol is a bioenergy source for the future, there is a need to investigate economical ethanol production from available raw materials. Ethanol could decrease the dependence on foreign oil and give an opportunity to the potato industry by using their waste product as a carbon source. However, ethanol fermentation from waste potato still needs to best studied to optimize the fermentation process.

THESIS ORGANIZATION

In our thesis we try to make ever thing separated our project work and outlines are discussed In different chapters. In every chapter there are many portion where we try to discuss in Detail.in chapter 1 we give the introduction of our thesis, why we did this work and how this Will help in environment. we try to feature a new source of renewable energy. Therefore,

Renewable energy sources attract attention to protect the environment, and to supply our energy Needs by reducing dependence on foreign oil and non-renewable energy sources. Then we Discussed our literature review where we give where from we get the idea and working prospects. While working on this thesis we get to know that in near future this renewable source would be a promising source.in chapter 2.3 we discussed about bio fuel ,bio gas and bio diesel. Here we also give the working methodology and principle of making ethanol. We give detailed about microorganism growth and how it works on our making starch .we discussed simultaneous

Scarification and fermentation process.in chapter 3 we discussed about our goal regarding this Project. Material and methods we discussed in chapter 4.from begging to end each and every Detailed anre included here .From obtaining starch to producing ethanol are described here.in Chapter 4 we discussed the result and discussion of our thesis .we evaluate the plant volume and Production rate.we also obtained the value of plant diameter ,rotation of propeller and also the Working power output of total plant for 10000 litre ethanol production.at chapter 6 we give the Conclusion part .our future work and future possibility regarding our project.in chapter 7 we give The references very correctly and the sources from where we took help during our thesis .at the Very last chapter we write down the nomenclature of our thesis.

LITERATURE REVIEW

2.1 Introduction

During the last decade, demand for energy has been increasing while environmental issues have become more important. Society has realized that oil fuel is depleting and is also not an eco-friendly energy source. Therefore, renewable energy sources attract attention to protect the environment, and to supply our energy needs by reducing dependence on foreign oil and non-renewable energy sources. Bioenergy, one renewable energy source, is a potential alternative to petroleum derived fuels and has the potential to help meet the increasing demand for energy for industrial processes, heating, and transportation (Balat et al., 2008). Types of bioenergy are: Biogas, biodiesel, bio-ethanol, natural gas, etc. Biogas is a digestion of the organic matter by anaerobic microorganisms under controlled conditions, whereas, biodiesel is a chemically processed fuel in which fatty acids are transferred to methyl esters and glycerin by trans esterification. Natural gas is a fossil fuel, so while it is clean and safe, it is not renewable. Bio–ethanol, a product of fermentation, has been utilized as a bio-fuel, a beverage, and an industrial alcohol. Most of produced ethanol (73%) is utilized as fuel, while percentages of beverage and industrial ethanol are 17% and 10%, respectively (Sanchez and Cardona, 2008). Moreover, bio-ethanol is already being used in pure form or blended with gasoline for transportation in Brazil and some other countries (de Oliveria et al., 2005). Bio-ethanol is also one of the components of a fuel called gasohol or E10 (10% ethanol by volume) and is available for transportation use in some states of the U.S. (Balat et al., 2008). It is recognized that use of bio-ethanol as a fuel may be one of the solutions to global warming and reducing dependency on foreign oil. Microorganisms that are ethanol-fermentative, such as Saccharomyces cerevisiae, can use organic feedstock as a raw material to produce ethanol. Different types of organic materials, such as starchy materials, lingo cellulosic materials, and sucrose- containing materials, can serve as a raw material for ethanol production. Potato, a starchy material, is one of these feedstock. The ultimate of potato utility depends on its applicable sugar content. This literature review will present background information about environmental problems due to fossil fuel consumption, bio-ethanol, and ethanol producer microorganisms, raw materials and methods of ethanol fermentation, and potato as a medium ingredient for ethanol fermentation.

2.2 Environmental Issues Related to Fossil Fuels

The climate of the Earth has slowly changed since the last ice age. The years following Industrial Revolution were wrought with human activities that have affected the climate by changing negatively the composition of the atmosphere (EPA, 2008a). These activities have caused environmental problems such as: Acid rain, air pollution, global warming, and ozone depletion. Flooding, starvation, drought, reduction of crop capacity, and extinction have occurred more often than in the past from these climate changes.

Carbon dioxide occurs in the atmosphere from the burning of fossil fuels (oil, natural gas, and coal), solid wastes, trees, wood products, and also as a result of other chemical reactions (e.g., manufacture of cement). It is possible to slow the greenhouse effect by decreasing emissions of heat trapping gases. The use of biofuels and renewable energy sources could decrease GHG emissions when the demand of energy is met. As an alternative for fossil fuels, biomass, hydro, solar, wind, and bioethanol can be listed as renewable and alternative energy sources (EIA, 2008b).

2.3 Bioenergy

Bioenergy is the production of products including electricity, liquid, solid, and gaseous fuels, heat, chemicals, and other materials from renewable energy sources. Bioenergy is clean, pure, non-polluting energy. Bio-ethanol, biogas, biodiesel, and natural gas are examples of bioenergy.

2.4.1 Biogas

Biogas is a digestion of organic matter by anaerobic microorganisms under controlled temperature, moisture, and acidity conditions and the main component of biogas is methane (das Neves et al., 2009). Methane is a colorless, tasteless, and odorless gas. Biomass can be produced from different raw materials, e.g., animal manure, algae, landfill, residues of the food industry, etc.

Biogas is produced in four main steps which are: Hydrolysis, acidogenesis, acetogenesis, and methanogenesis in the study of das Neves et al. (2009). Hydrolysis is transformation of insoluble compounds to soluble compounds. In the second step, acidogenic bacteria ferment hydrolyzate to hydrogen, carbon dioxide, and acidic compounds. The following step is acetogenesis and acetogenic bacteria forming acetic acid. In methanogenesis, the last step, methanogenic microorganisms convert hydrogen, carbon dioxide and acetic acid to methane. Production of biogas can manage solid wastes and supply energy for heating, transportation etc. In middle-income and developing countries. However, anaerobic fermentation of biogas is a very slow process which increases the cost of fuel. Another issue, the greenhouse effect of biogas is 21 fold higher than carbon dioxide and must be stored and managed carefully (das Neves et al., 2009).

2.4.2 Biodiesel

Biodiesel is a renewable, environmentally safe, and energy efficient bioenergy. In the production of biodiesel, fatty acids are transferred to methyl esters and glycerin by trans-esterification, which is catalyzed by an alkali or acid. Although any fatty acid can be a raw material for the production of biodiesel, waste vegetable oil and animal fats are preferred due to the fact that they are not food value products (Refaat, 2010).

Production of biodiesel from waste oil starts with pretreatment of raw material, which includes filtration to remove dirt, food residues, and non-oil materials. After determining the concentration fatty acid, trans-esterification is performed to obtain biodiesel. Trans-esterification is a reaction in which fatty acids convert to methyl esters and glycerin. Korus et al. (1993) reported that the ratio of alcohol to vegetable oil, temperature, rate of agitation, and amount of water present in the reaction mixture are essential parameters of the trans-esterification process. Temperature has no significant effect on ester conversion except decreasing required conversion time. Because heating costs are of concern, the trans-esterification reaction is carried out at room temperature (Korus et al., 1993). Moreover, a homogenous mixture of alcohol and oil increases conversion as well as decreasing the time required to reach maximum conversion (Korus et al., 1993).They also reported that some catalysts can be used to improve trans-esterification such as: Potassium hydroxide, sodium hydroxide, sodium methoxide, or sodium ethoxide. Separation of alcohol and glycerin follows trans-esterification in the production of biodiesel. Separated alcohol is washed before commercialization to remove the catalyst from ester.

2.5 Bio-ethanol

Ethanol, which is known as pure alcohol, ethyl alcohol or bio-ethanol, is a colorless, flammable, volatile liquid with a strong odor. The melting point of ethanol is –114.1°C, whereas it boils at 78.5°C. Due to the low freezing point of ethanol, it has been using in thermometers for temperatures below –40°C, and automobile radiators as antifreeze (Shakhashiri, 2009). The properties of ethanol are given in Table 2.1. The chemical formula of ethanol is C2H5OH, contain a –OH group bonded to carbon. Ethanol can be produced synthetically and naturally by yeasts. Ethanol fermentation has been used for the production of alcoholic beverages, and for the rising of bread dough for centuries; recently, it has been produced to use industrially. Since 1908, fuel ethanol has found use for transportation gasoline and today, 73 % of ethanol production is consumed as fuel worldwide. Bio-ethanol has become an attractive fuel because it is renewable and oxygenated (Balat et al., 2008). Sanchez and Cardona (2008) indicate that oxygenated ethanol reduces the emission of carbon dioxide and aromatic compounds.

Table 2.1 Properties of ethanol

Description	**Values**
Chemical Formula	C_2H_5OH
Molecular weight (g/mol)	46
Density at 20°C (kg/m³)	789

Calorific value (MJ/kg)	26.9
Calorific value of stoichiometric mixture (MJ/m³)	3.85
Heat of evaporation (kj/kg)	840
Temperature of self-ignition (K)	665
Stoichiometric air/fuel ratio (kg air/kg fuel)	9
Lower flammability (λ_1)	2.06
Higher flammability (λ_h)	0.3
Kinematic viscosity at 40°C (mm²/s)	1.4
Motor octane number /research octane number	89/107
Cetane number	8
Flame temperature (K)	2235
C (%)	52.2
H (%)	13
OH (%)	34.8

Ethanol is also non-toxic, and is a non-contaminant to water sources. Compared to the other fuel additives such as methyl tertiary butyl ether (MTBE), ethanol's octane booster properties are greater (Sanchez and Cardona, 2008). Bio–ethanol is being used purely or blended with gasoline for transportation in Brazil and in some states of the U.S. (de Oliveria et al., 2005; Balat et al., 2008). Although bio-ethanol has been introduced as an alternative to petroleum-derived fuels, corrosiveness, low flame luminosity, low vapor pressure (compared to gasoline), miscibility with water, and low energy density are some of the disadvantages of bio-ethanol (Balat et al., 2008). Aside from fuel, ethanol has other applications in various industry branches such as: Personal care products, cleaning agents, pharmaceuticals, and beverages.

2.6. Production of Bio-ethanol

In 2006, worldwide bio-ethanol production was approximately 51.3 billion liters (Balat et al., 2008). An increase in fuel ethanol production resulted from the fact that many countries want to reduce dependency on foreign oil and enhance air quality.

Bio-ethanol can be produced from different feedstock, such as corn, sugar cane, cellulose, potato, etc. Sugar cane, as a raw material, is used for 60% of global ethanol production, while 40% of global production of ethanol comes from other crops. Corn grain is the main raw material of ethanol production in the United States (90%) whereas in Brazil, sugar cane is the major source (Balat et al., 2008). Desirable raw materials for ethanol fermentation should have applicable sugars that can be fermented by microorganisms. Sucrose containing feedstock, starchy feedstock, and lignocellulose biomass can be used as raw materials for ethanol production.

Ethanol fermentation is summarized with the chemical equations:

$C_6H_{12}O_6 \rightarrow 2\ CH_3COCOO^- + 2H^+$

$CH_3COCOO^- + H^+ \rightarrow CH_3CHO + CO_2$

$CH_3CHO + NADH \rightarrow C_2H_5OH + NAD^+$

2.6.1 Producer Microorganisms of Bio-ethanol

Microorganisms meet their energy demand by converting the carbon sources to by-products such as: carbon dioxide, lactic acid, ethanol, cellulose. Ethanol is one of the end products of fermentation, which can be performed by either bacteria or yeasts. Fermentation is an energy generation process with no electron transport mechanism (Shuler and Kargi, 2008).

Saccharomyces cerevisiae has generally been recognized as safe (GRAS) and is the most commonly used microorganism in the fermentation industry (Kunz, 2008). Production of alcoholic beverages and bread dough rising are the two main responsibilities of S. Cerevisiae. Alcohol production occurs by converting sugar to energy, and simultaneously S. Cerevisiae meets its metabolic energy need. Fermentation is carried out in an anaerobic environment, but S. Cerevisiae needs small amounts of oxygen to synthesize fatty acid and sterols (Sanchez and Cardona, 2008). Although S. Cerevisiae is the most common microorganism in ethanol fermentation, it is not able to break down lingo-cellulosic and starchy material. One approach to solve this problem is hydrolysis before the fermentation process, which converts the unfermentable sugars to glucose by hydrolyzing enzymes. In pretreatment for hydrolysis, either mixed cultures or genetically modified micro-organisms can be introduced. S. Cerevisiae already has some modified strains to enhance the ethanol yield and assimilate pentose's (Cardona and Sanchez, 2007).

2.6.2. Feedstock for Ethanol Fermentation

Bioethanol can be produced from different feedstock including sugar containing feedstock, starchy feedstock, and lingo-cellulosic feedstock. For ethanol fermentation, raw material plays an important role in production costs (Cardona and Sanchez, 2007). Since 30% of medium costs affect the cost of product, composition of media is very important (Lee et al., 1998). By decreasing the cost of medium, cheap ethanol can be produced without sacrificing ethanol yield and biomass. The plant design and the process of fermentation is directly related to the type of raw material. Sugars can be transferred to ethanol without any pretreatment, however starchy and lingo-cellulosic materials need pretreatment prior to the fermentation process. The pretreatment of starch involves hydrolysis, whereas lingo-cellulosic materials require more complicated treatments.

2.6.2.1. Sugars as a Feedstock for Ethanol Fermentation

Sugars, hexo and pento carbons, do not require pretreatment, such as hydrolysis, prior to being fermented. Thus bio-ethanol fermentation is easier, compared to starchy materials or lingo-cellulosic feedstock, when the raw material is already in the form of sugar. However, the limitation of sugars is their high cost, because they are already valuable as a food source. In addition, availability and transportation costs of sugar containing raw materials increase the cost of ethanol production (Cardona and Sanchez, 2007).

2.6.2.2. Lignocellulosic Biomass as a Feedstock for Ethanol Fermentation

This group of bio-ethanol feedstock consists of agricultural residues, wood, and energy crops (fast growing and low cost agricultural production). Rice straw is also another lingo-cellulosic waste material (Balat et al., 2008). Lignocellulosic materials need to undergo very complex pretreatments prior to the fermentation process. Five main steps have been used to produce ethanol from lingo-cellulosic biomass: biomass pretreatment, cellulose hydrolysis, fermentation of hexoses, separation and effluent treatment (Cardona and Sanchez, 2007). Lignocellulosic biomass has a huge potential for bio-ethanol production; however, the cost of production of bio-ethanol is high due to the expense of a pretreatment process using current technologies.

2.6.2.3 Starch as a Feedstock for Ethanol Fermentation

Starch is a polysaccharide composed of amylose and amylopectin, both of which are glucose units. Amylopectin, which is highly branched by short chains, is 70-80% of starch by composition. Amylose, a linear polysaccharide formed by α-1, 4-linked glucose residues is the minor component of starch (20-30%) (Eksteen et al., 2003). Figure 2.6 illustrate the structure of amylose.

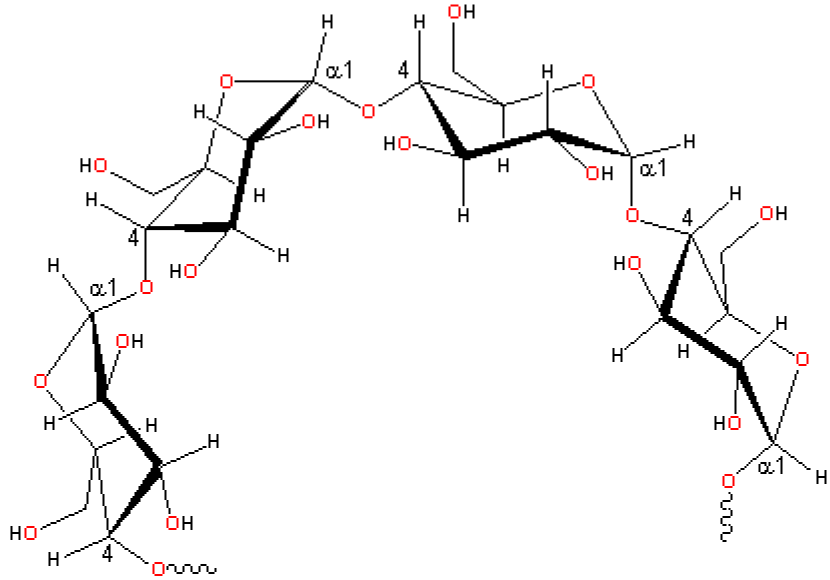

Figure 2.1 Representative partial structure of amylose

Hydrolysis is a process of breaking down amylopectin and amylose linkages into fermentable sugars and is needed before the fermentation of starch materials. Hydrolysis is carried out at high temperature (90-110ºc0. At low temperatures, hydrolyzing of starch is possible and can contribute to energy savings (Sanchez and Cardona, 2008). To convert starch into fermentable sugars, either acid hydrolysis or enzyme addition should be done. Both hydrolysis methods have disadvantages and advantages. The limitations of acid hydrolysis include the by-products inhibition on growth of yeast (such as 5-hydroxymethylfurfural (5-HMF)), neutralization before fermentation, and expensive constructional material (Tasic et al., 2009). On the other hand, high prices of enzymes play a crucial role when feasibility is of concern for enzyme hydrolysis. Enzyme hydrolysis is chosen despite the high cost of enzymes and initial investment (Tasic et al., 2009) because of the high conversion yield of glucose. Moreover, starch has extended storage and a low transportation cost with the pretreatment cost of starch still competitive with pretreatment of lingo-cellulosic raw materials (Abouzied and Reddy, 1986).

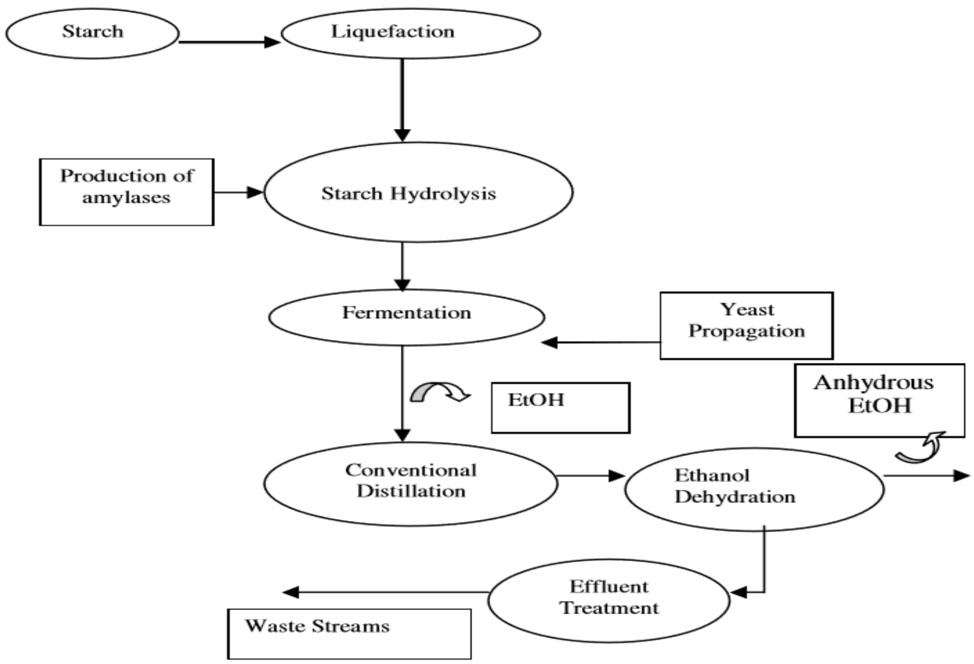

Figure 2.2 Ethanol production from lignocellulose materials

2.6.3. Fermentation

Fermentation is a metabolic process of microorganisms to obtain energy by breaking down organic compounds. While microorganisms derive their energy, some byproducts are: lactic acid, butane, carbon dioxide, ethanol, cellulose, nosing. In ethanol fermentation, derivation of energy from sugars by either yeast or bacteria, produce carbon dioxide and ethanol are produced. Because yeasts produce their energy without the need for oxygen, ethanol fermentation is a facultative anaerobic process.

Fermentation methods are other 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.

2.6.3.1. Batch Processes

Batch fermentation is carried out in a cultured vessel with an initial amount of medium and during the fermentation no medium addition or removal occurs (Shuler and Kargi, 2008). Ethanol fermentation is performed after sterilization of the media and adjustment of ph by either acid or alkali. After inoculation of yeast or bacteria, production of ethanol takes place by controlling temperature, ph, agitation, and aeration depending on the characteristics of the cultured microorganism.

2.6.3.2. Fed-Batch Processes

Fed-batch process can decrease the disadvantages of batch fermentation. In this process, fresh sterile medium is added to a reactor continuously, while fermentation broth is either removed semi-continuously or not removed. By addition of medium, two benefits can be obtained; microbial growth will not be affected due to lack of nutrients and substrate inhibition will be overcome, if it is a limitation for the process. Ethanol is a metabolic inhibitor for yeast and a point of concern in fermentation, which will be eliminated in the use of fed-batch process.

2.6.3.3. Continuous Process

Continuous process, which is also known as chemostat, continuous-flow, or stirred-tank fermentation, involves fresh sterile media fed into a reactor continuously. In addition to feeding the reactor with fresh nutrients, the effluent is removed from the reactor and the volume of the reactor always is constant. The rates of feeding and removing are also equal. To avoid wash-out, which means taking away all the cells from the reactor, growth rate of the microorganism is chosen as a rate of removing cells (Shuler and Kargi, 2008).

Advantages of continuous process over batch fermentation are low construction costs of bioreactors, lower maintenance and operational requirements, higher yield, and a better control of the process (Sanchez and Cardona, 2008). Stability of culture, however, is an issue for continuous fermentation. Even small changes in any of parameters, such as: temperature, dilution rate, substrate concentration of feed etc., can decrease yield.

2.6.4 Simultaneous scarification and fermentation (SSF)

There is no process which can give the best productivity, yield, and economic feasibility at the same time. To attain the maximum ethanol yield and reduce the cost and time, integration of processes is very effective. By integration of processes, several operations combine and perform at the same unit. Since the pretreatments play a crucial role in production of ethanol, most of the process involve integrated hydrolysis and fermentation.

Simultaneous saccharification and fermentation (SSF) is one of the common processes. SSF found application to ethanol production in the starch-processing industry in the 1970’s (Madson and Monceaux, 1995). After liquefaction, saccharification and ethanol fermentation are carried out simultaneously. The benefit of this process is elimination of substrate inhibition. Because the glucose is transferred into ethanol right after its conversion from polysaccharides, no accumulation of glucose occurs in the media. In addition, the hydrolysis reactor is not needed (Cardona and Sanchez, 2007). The drawback of SSF is that both saccharification and fermentation have different optimal conditionals to obtain maximum yield, and it is difficult to optimize parameters for both hydrolysis and fermentation. Optimizing temperature is especially an issue, because hydrolysis of starch requires a high temperature, whereas high temperature is an inhibitor for ethanol production. Costs of enzyme is of concern because more enzyme is needed for a high yield (Cardona and Sanchez, 2007).

2.6. Bio-plastic Materials

Bio-plastics are plastic materials made from renewable biomass sources, such as vegetable fats and oils, corn starch, straw, woodchips, recycled food waste, etc. Bio-plastic can be produced from agricultural by-products and also from used plastic bottles and other containers using microorganisms. Common plastics, such as fossil-fuel plastics (also called petro-based polymers) are derived from petroleum or natural gas.

2.6.1. Process for making Plastics

The process can be started by charging 60ml of distilled water in a beaker or container. Then, the potato starch is charged into the water. Start stirring and agitating till to get a homogenous suspension. Then the glycerin should be mixed with the solution. As it is pretty thick, all of it should be poured inside properly. Then, vinegar should be added and again mix it all up. About 200^0C temperature should be applied to the mixture and continue stirring.

POSSIBLE OUTCOMES

- We obtained very good quality of starch from waste potato
- After that we get ethanol our desire bio fuel
- Using our obtaining starch we produced bio plastic after several heat treatment process
- We get bio fuel which is a source of energy and get bio plastic which is very environment friendly

GOALS & OBJECTIVES

The energy demand of the world has been increasing due to an increasing population. Bioenergy is an alternative renewable energy. The production of ethanol, a type of bioenergy, has already occurred all over the world. However, the conventional raw materials are high value products, such as corn, wheat, cellulose, potato, and sugarcane. Feedstock, which have already found, use as food. Low value or waste by-products should be utilized for ethanol production to meet the energy demands. Therefore, the main goal of this research is to utilize potato mash waste as a carbon source for Saccharomyces cerevisiae for the fermentation of ethanol. Another goal is to produce bio-plastic from obtained potato starch.

Objectives:

- Extracting Starch from Potatoes.
- Production of Bioethanol by starch Fermentation.
- Continuous Fermentation Plant Design for Bioethanol Production in a large Scale.
- Bio-plastic Production from Starch.

MATERIAL & METHODOLOGY

4.1 Potato Sample collection

The total production of potato in Bangladesh is 10215957 metric tons according to 2016-17. The total land for using potato production is about 1234871 acres (Bbs.gov.bd. 2019). Cold storage, one of the method of food preservation, maintains temperature within the range about 10-15^{0}C (Opentextbc.ca. 2019). It is necessary in Bangladesh because the maximum temperature is always above 16 even in the winter session. Freshly harvested potato and other vegetable contain more than 70% of moisture and as a result these are perishable in nature.

The production plant should be set up near the cold storage due to minimizing the transportation cost. The target for this experiment is to produce one thousand liters (equivalent to 0.78 metric tons) ethanol per day. The potato sample was collected from the North Bengal region of Bangladesh.

Figure 4.1: Potato Samples

4.2 Starch Extraction

For the extraction of starch, it is necessary to follow some steps. At first, the type and the amount of potatoes should be selected extraction. For this, we have selected one kg potato for starch extraction. The potato samples should be stored in a certain place. Then, the sample of potatoes should be peeled by using a potato peeler. A cheese grate has to be used for grating them up.

The starch we need to extract is stored inside the cells of the potatoes and to get the starch out,

Figure 4.2: Using cheese grate to grate the potatoes

cells need to be destroyed. After shredding all the potatoes, a bunch of lukewarm water should be added.

The amount of water added with the shredded potatoes depends on the amount of potato shavings. When the potatoes are shaved, a lot of cells are destroyed and they released their starch. It's better to try to wash away the starch into the water. A mixture of potato shavings and starch will float around the container. The next thing is to pour off the liquid from the container. The washing potato shavings process should be continued three or four times. The liquid has to be collected in another container where the starch will settle out slowly at the bottom. After waiting about an hour, a quite bit of starch can be seen at the top of the liquid. Then the liquid should be decanted into another container. A strainer has to be set with a beaker to filter the starch-potato mixture.

Figure 4.3: Hydrolysis

Figure 4.4: Using Strainer to Wash the water

To get rid of any starch remain in the container, some more water will be added through the container to beaker. The brown water from the beaker should be decanted and remaining portion contains the starch. To clean the starch up, a little amount of distilled water has to be poured in. Mixing the things inside the beaker completely well, a spoon is used to collect each and every starch from the beaker and wait some days to dry the starch.

Figure 4.5: Starch in a dense form

Leaving the things three or four days out, some amount of potato starch will be obtained. The amount of starch is about 20 grams.

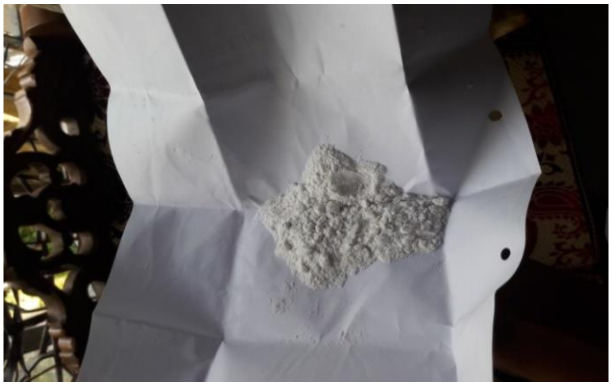

Figure 4.6: Dry Starch

Table 4.1: Different chemical properties of the obtained starch

Cholesterol	6%
Sodium	1%
Carbohydrate	2%
Vitamin A	94%
Calcium	4%
Vitamin C	11%
Iron	2%

Ethanol is related to starch composition in potato waste, conversion of starch to glucose, and conversion of glucose to ethanol. The moisture content of potato in is 15.1% and 43.1% (wet basis) at temperature 25^0C to 75^0C (Zhu, Z. And Guo, W. 2017).

Starch + Water → Glucose

Glucose → Ethanol + CO_2

The first step of ethanol is related to starch composition in potato waste, conversion of starch to glucose, and conversion of glucose to ethanol. The moisture content of potato in is 15.1% and 43.1% (wet basis) at temperature 25^0C to 75^0C. Assuming 100% efficiency for both conversion processes, a total of 5 metric tons per day of potato is needed to produce 100 kg starch, which will need for fermentation of ethanol.

4.3 Microorganism preparation

Saccharomyces cerevisiae, Baker's yeast DS28911 is used for this experiment. The parameter for the culture growth is described in Table 1, and was sterilized after dissolving the contents (total 120 ml) in conical flasks. The selective medium will be inoculated with the culture and incubated at 30^oc for 50 hours, and then stored under 5^oc.

Figure 4.7: Baker's Yeast Sample

Table 2: Parameters of Saccharomyces cerevisiae DS28911

Potato Waste Medium for DS28911	Composition for Selective Medium	Kinematic Parameters for DS28911
Potato Waste (50g/L)	Glucose (50g/L)	μ_{max}= 0.36h^{-1}
Yeast (5g/L)	Yeast (6g/L)	$Y_{x/s}$= 0.2g of biomass/g of substrate
$(NH_4)_2SO_4$ (5g/L)	$(NH_4)_2SO_4$ (5g/L)	K_s= 6.5g/L
KH_2PO_4 (3g/L)	KH_2PO_4 (3g/L)	$Y_{p/s}$= 0.2 g of biomass/g of substrate
$Mgso_4.7H_2O$ (0.5g/L)	$Mgso_4.7H_2O$ (0.5g/L)	X_m= 50g/L
$Znso_4.7H_2O$ (0.045g/L)	$Znso_4.7H_2O$ (0.045g/L)	X_0= 10g/L

$CaCl_2.2H_2O$ (0.045g/L)	$CaCl_2.2H_2O$ (0.045g/L)	$Q_{O_2} = 3.7$

Some Operations should be performed like blending, sieving, liquefaction, saccharification, dilution, sterilization by step by step before entering for the fermentation. At first, Blending should be performed. Then, small amount of $(NH_4)_2SO_4$ should be added for preventing the growth of harmful microorganisms. Potato mash will be adjusted to ph 5 with 2M H_2SO_4. Liquefaction of potato waste should be done by adding 15 ml/L of alpha-amylase enzyme and incubate at 90^{o}c. For the process of saccharification, 0.7 ml/L of amyloglucose will be added to liquefy potato waste and incubate at 50°C for 70 hours. Later, the feed solution should be sterilized at 100^{o}c for 30 minutes. Finally, ethanol will be separated from the fermentation chamber in a continuous distillation system (Jiménez-Islas, D., Paez-Lerma, 2014).

Figure 4.8: Obtained Bioethanol Sample

4.4 Bioreactor Preparation

The bioreactor corresponds to one pre-fermenter, where aerobic fermentation will take place from the biomass. One continuous aerobic fermenter will also be used for the purpose of increasing the concentration of biomass (Najafpour, G. 2007). Aerobic fermentation will occur in presence of oxygen. For this process, the dissolved oxygen should be controlled as high as possible by increasing Oxygen transfer rate. For large scale bioreactors, the surface area will be decreased (Cheng, K. 2015).

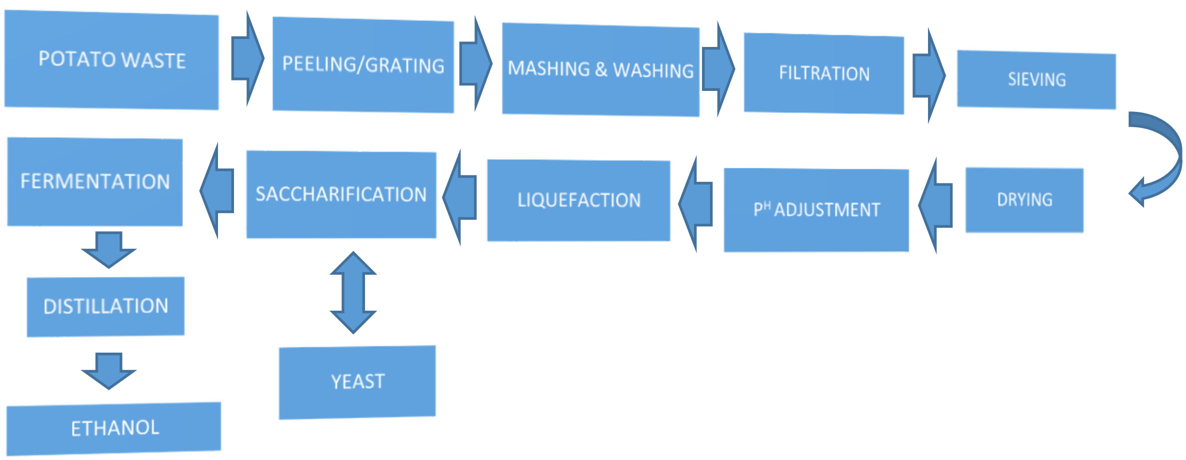

Figure 4.9: Block Diagram for the Process

4.5 Continuous System Design

The initial assumptions of S_0, P_0, X_0, X_1 are 100g/L, 0g/L, 0g/L & 30g/L.

The targeted production per day is 1000litres.

If, 10 hours of work are performed per day, then the production rate is 100 liters per hour. For this process, two parallel systems, one is aerobic reactor and another is anaerobic reactor is used.

From Table 2, $Y_{X/s}$ = 0.2g of biomass/g of substrate.

$Y_{X/S}= (X_1-X_0)/(S_0-S_1)$ (1)

From this equation 1, the Substrate Concentration leaving the continuous aerobic fermenter, S_1 = 50g/L

$D_1= \mu_1= (\mu_{max} \cdot S_1)/(K_s+S_1)$ (2)

From this equation 2, the dilution rate for the aerobic fermenter, D_1 = 0.31hour^{-1}

$2F_2$=Production rate *$\rho_{ethanol}$* $1/P_1$ (3)

If, the density of ethanol is 789kg/m^3, then from the equation 3, the flow rate leaving the aerobic reactors will be 789Lh^{-1}.

$F= D_1V_w$ (4)

From the equation 4, the working volume, V_w= 2.54m^3.

For this system, assuming α = 1.2,

$D_2= \alpha f/V_w$ (5)

Assuming the reactor volume is same. Then, the dilution rate for the anaerobic fermenter, D_2=0.37hour^{-1}.

Assuming the head space as 10%, the total volume of the continuous fermenters is found to be $2.8m^3$. The diameter (D_c) and height (H_c) of the fermenter are calculated based on 1/2 aspect ratio, and found to be 1.2 and 2.4 m, respectively.

$$(\frac{dx}{dt})_G = \frac{\mu_{max}*(S_0-(\frac{X}{Y_{X/s}}))}{K_S+(S_0-\frac{X}{Y_{X/S}})}*X_0 \qquad (6)$$

Assuming, X_1=30g/L, from equation 6, X_2=12.4g/L.

$$Y_{p/x} = \frac{Y_{p/s}}{Y_{x/s}} \qquad (7)$$

For the anaerobic fermenter, according to equation 7, $Y_{p/x}$= 1g/g.

$$P_2=Y_{p/x}*(X_1 - X_2) \qquad (8)$$

From equation 8, the final product concentration, P_2= 17.6g/L.

$$\mu_2 = D_2\ (1 - \frac{X_2}{X_1}) \qquad (9)$$

For the anaerobic fermenter, according to equation 9, μ_2= $0.217h^{-1}$.

$$S_2 = S_1 + \propto S_0 - \frac{\mu_2 X_2}{D_2 Y_{x/s}} \qquad (10)$$

According to equation 10, the final substrate concentration, S_2= 109.67g/L.

$$t_{exp} = \frac{1}{\mu_{maz}} \text{Ln}(\frac{X_m}{X_0}) \qquad (11)$$

According to equation 11, the time of exponential growth, t_{exp}=4.47 hour.

If, the working volume of batch fermenter is 2% of the continuous fermenter, then the volume of batch fermenter is $0.024m^3$.

$V_T = 3.14\frac{{d_B}^3}{2}$ (12)

Assuming, head space is 10%, so the total volume of batch fermenter, V_T=0.106m^3 with a diameter of 0.4m and height of 0.8m.

Aeration is important for aerobic fermentation and is used to meet oxygen demand of yeast on fermentation. Oxygen Uptake Rate (OUR),volumetric oxygen transfer coefficient (k_{la}), superficial gas exit speed, total orifice area, and number of nozzles required are also be calculated. Agitation is needed to supply homogeneous mixture for the fermenter. Agitation enhances the oxygen transfer rate (OTR) by breaking the air into bubbles, increasing the surface area.

Dissolved oxygen (DO) is also a vital parameter in aerobic fermentation, and may be a limiting substrate. Sprinkling air through the fermentation chamber can inaugurate oxygen into the system. Oxygen uptake rate is the oxygen consumption rate for the microorganisms to grow. Oxygen uptake rate is represented below where Q_{O2} is the specific rate of oxygen consumption and X is the cell concentration. In this experiment, the supply of oxygen should match the maximum requirement when microorganisms reach the maximum biomass concentration (X_m).

OUR= (Q_{O_2})*X_m (13)

Maximum biomass concentration for continuous reactor is 50g/L. According to equation 13, OUR= 5.8go_2/Lh.

The impeller diameter is assumed to be 15% of the reactor diameter. So, the diameters of impeller for the batch and continuous fermenter are 0.061m and 0.18m.

Reynolds Number of the impeller is given in equation 16.

$$Re_i = \frac{\rho N(d_i)^2}{\mu} \qquad (16)$$

From Reynolds number, the impeller speed can be calculated from equation 17.

$$N_i = \frac{Re_i * \mu}{\rho * {d_i}^2} \qquad (17)$$

For the batch fermenter, assuming Reynolds number is 1000, the speed of the impeller, N_i = 338.8rpm. Here, The value of dynamic viscosity, μ=0.98mpas for 30^0C.

For the continuous fermenter, assuming Reynolds number is 10000, the speed of the impeller, N_i= 383.3rpm. The type of impeller chosen for this experiment is propeller due to cost minimization.

$$P_{no} = \frac{P_g}{\rho * N^3 * {d_i}^5} \qquad (18)$$

According to the chart of impeller power number vs. Impeller Reynolds number for different impeller types; P_{no} For marine impeller at Re=1000 is 0.5, and at Re=10,000 is 0.4.

$$P_{gb} = P_{no} * \rho * N^3 * D_i^5 \qquad (19)$$

According to equation 19, for batch fermenter, impeller power is 12.9W. For continuous fermenter, impeller power is 3358W.

On the last step of ethanol fermentation, the medium stock contains the desired product, biomass, and varying amounts of other wastages, e.g. Mineral salts, organic acids, etc. In the continuous submerged fermentation, the biomass is difficult to be removed from fermentation stock due to the viscosity of the potato mash. In the first step, fermented stock (also called beer) is processed through a fermented mash where steam is used to slice off all of the ethanol, along with some water, from the slurry. The assumptions for calculating the filtration are $\varphi=0.5$, $\Delta P=0.0025\ N/m^2$, n=100 rpm, $r_m=10m/kg$.

$$V_0 = \frac{r_m}{\alpha c} * A \qquad (20)$$

According to equation 20, the continuous rotary mash column has to filtrate 100L fermentation stock per hour with a filtration area of $4.16m^2$ in order to meet the whole system.

After removing the biomass and wastes in the filtration process, continuous distillation is carried out where ethanol is segregated from water based on the differences in boiling. The product is ready to leave the distillation columns contains about 97% ethanol by volume. The final product from the molecular sieve system is 99% pure ethanol vapor, which will be further condensed and mixed with denaturant (e.g. Gasoline) and stored in tanks before being transported for sale as an alternative fuel additive (Najafpour, G. 2007).

4.6 Bio-plastic Formation

Bio-plastics are plastic materials made from renewable biomass sources, such as vegetable fats and oils, corn starch, straw, woodchips, recycled food waste, etc. Bio-plastic can be produced from agricultural by-products and also from used plastic bottles and other containers using microorganisms. Common plastics, such as fossil-fuel plastics (also called petro-based polymers) are derived from petroleum or natural gas. Not all bio-plastics are biodegradable nor biodegrade more willingly than commodity fossil-fuel derived plastics. Bio-plastics are usually made from sugar derivatives, including starch, cellulose, and lactic acid. As of 2014, bio-plastics illustrated approximately 0.2% of the global polymer market (300 million tons).

4.6.1 Necessary Equipment

For this experiment, the starch powder extracted from potatoes is needed. The materials are:

- 10 grams of Starch
- 60ml Water
- 5ml glycerin
- 5ml 5% Acetic Acid in water or vinegar
- Silicon baking sheet

4.6.2 Process

The process can be started by charging 60ml of distilled water in a beaker or container. Then, the potato starch is charged into the water. Start stirring and agitating till to get a homogenous suspension. Then the glycerin should be mixed with the solution. As it is pretty thick, all of it should be poured inside properly. Then, vinegar should be added and again mix it all up. About 200^0C temperature should be applied to the mixture and continue stirring.

Starches are polysaccharides or large branched polymer chains consisting of sugar molecules. For applying heat, the acetic acid hydrolyzes or breaks the bonds between the branches and this leaves long linear chains of polysaccharides or sugars ordinarily these linear chains are fairly stiff but for adding glycerin this acts as a plasticizer enabling the plastic to be somewhat flexible or not brittle. Now, after heating for a while, it ends up with thick viscous goo. If heating is continued a little longer, it turns clear to see. Then, the mixture is taken and poured it out onto a silicon baking sheet.

Thickness of the sheet should be controlled properly. After it is cooled down for sometimes, it will be a thick opaque layer which is almost like a gelatin on the foil. Due to very low thickness, a little bit plastic will be damaged after a week of drying. Finally, a plastic film can be produced by this process.

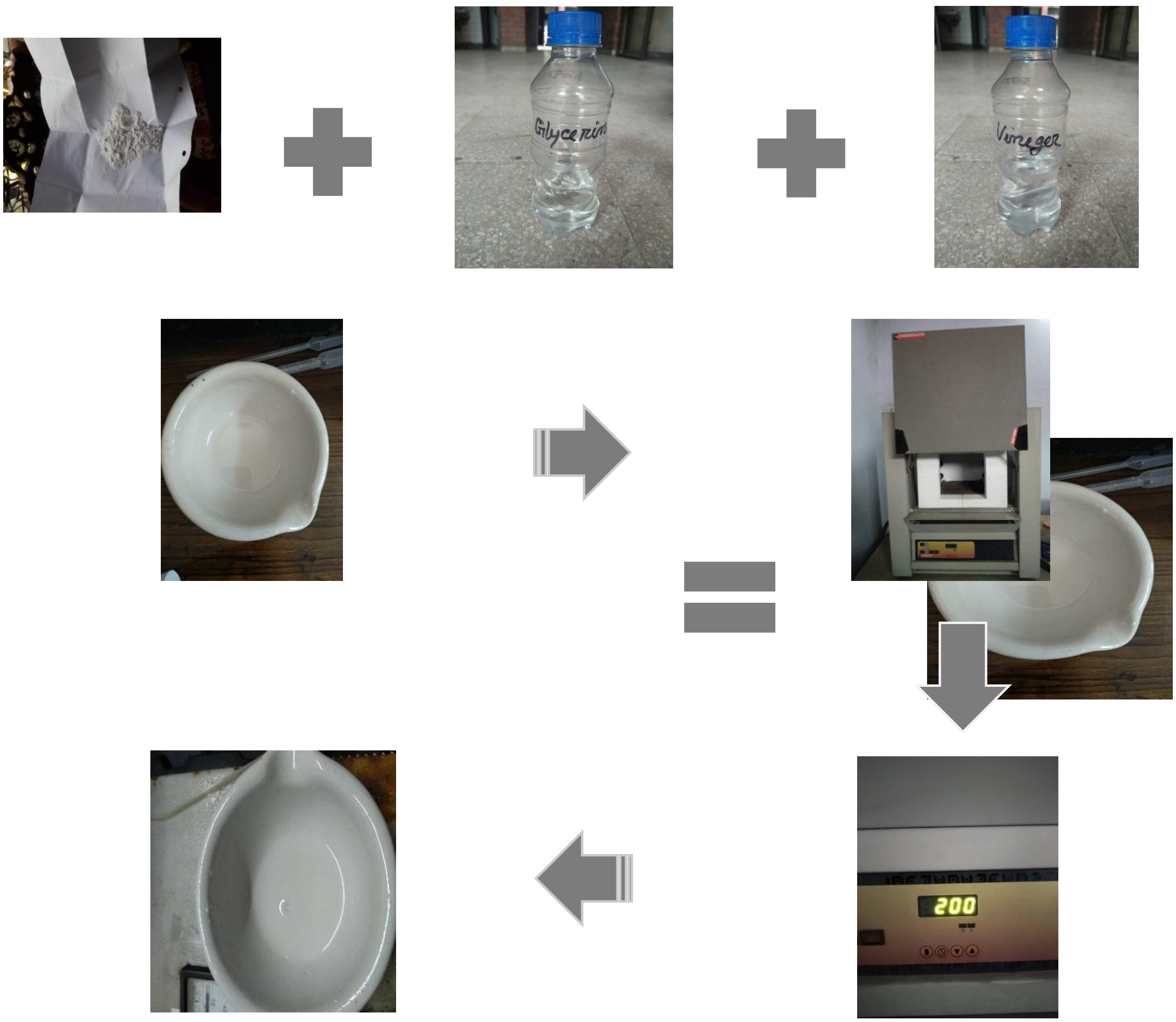

Figure 4.10: Bio-plastic Production Process

4.6.3 Properties

The properties of the plastics from starch are:

- The plastic films are very thin.
- Thicknesses are even despite to unevenness in the molding process.
- Strong and stretch resistant.
- Tear resistant.

RESULT & DISCUSSIONS

The batch fermenter (0.106 m^3) was constructed for the primary production of biomass. The tank was sterilized and the impeller with a diameter of 0.061m rotates at 338.8 rpm with 12.9W power. At the end of the fermentation, the ingredients with the biomass product (17.6 g/L) are pumped into the continuous aerobic fermenter.

The continuous anaerobic fermenter (2.8 m^3), which takes a stream from the continuous aerobic fermenter, was designed for the production of ethanol. Since the substrate concentration coming from the aerobic fermenter is less indeed (50 g/L), a stream of fresh medium, which has 3 times higher flow rate than the stream coming from the aerobic fermenter, is pumped to this reactor from the feed tank. This reactor has an impeller of same specifications as that of the continuous aerobic fermenter.

The greatest disclosure with the bioreactor design was to incorporate the anaerobic and aerobic fermentation parameters in to the system. This microorganism has different metabolisms under aerobic and anaerobic conditions. Especially, where the optimum conditions of reactors was determined, a number of growth and production parameters were selected from the literature to be in the range of both anaerobic and aerobic fermentation to help the construction of the total system.

Description	**Values**
Chemical Formula	C_2H_5OH
Molecular weight (g/mol)	46
Density at 20°C (kg/m^3)	789
Calorific value (MJ/kg)	26.9
Calorific value of stoichiometric mixture (MJ/m^3)	3.85
Heat of evaporation (kj/kg)	840
Temperature of self-ignition (K)	665
Stoichiometric air/fuel ratio (kg air/kg fuel)	9
Lower flammability (λ_1)	2.06
Higher flammability (λ_h)	0.3
Kinematic viscosity at 40°C (mm^2/s)	1.4
Motor octane number /research octane number	89/107
Cetane number	8

Flame temperature (K)	2235
C (%)	52.2
H (%)	13
OH (%)	34.8

Table: Properties of Ethanol

CONCLUSION & FUTURE WORK

The main objective of this work is to produce bio-fuel from cellulosic waste such as vegetables. As days progress the demand of energy increases as the natural sources of energy decreases. Due to lack of energy resources waste to energy is a must topic nowadays.

Our work focuses on the bio-ethanol production for waste potatoes. This work is done with well-organized step by step process. From collection of sample to starch extraction or micro-organism production for bio-reactor each and every step is well defined. Also mathematical equation for this experiment also given to design a perfect and effective bio-reactor for it. Hopefully this will pave the way for further research in waste to energy sector.

In this study, we find out another way of obtaining starch which is a good quality of raw material

Of producing bio fuel. After that we have produced ethanol from starch. We got to know that Our ethanol has a high calorific value than other available fuel. Our ethanol would be a new Source of fuel instead of fossil fuel. After that we made another thing named bio plastic. We Make the bio plastic using our available starch with adding some chemicals. The plastic we have Produced is bio degradable and very cheaply. The property we have observed is very much Satisfactory result. Generally, the plastic is not degradable but our plastic is bio degradable. and Its strength is higher than the conventional plastic. The scopes for future work are mentioned below:

- During our work we have found that the starch contained moisture which made Difficulties making starch. We will work on it to get better starch with less content of Moisture

- The ethanol we have got need to undergo some tests like calorific test, knocking number, sodium test etc.

- We will work on our obtaining bio plastic. We will do strength test, yield test, tearing test near future.

REFERENCES

Hahn-Hagerdal, B., M.Gable, M.F. Gorwa-Graslund, G. Liden and G. Zacchi. 2006. Bio Ethanol – the fuel of tomorrow from the residues of today. Trends in Biotechnology 24(12): 549-556.

Demirbaş, A. (2003). Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey. *Energy Conversion and Management*, 44(13), pp.2093-2109.

EPA. 2008(a). Climate Change. Available at: (http://www.epa.gov/climatechange/basicinfo.html). Accessed 30 September 2008.

Grassi, G. (1999). Modern bioenergy in the European Union. *Renewable Energy*, 16(1-4), pp.985-990.

Sanchez O.J. and Carlos A. Cardona. 2008. Trends in biotechnological production of fuel Ethanol from different feedstock. Bioresource Technology 99(13): 5270-5295.

Wheals, A. (1999). Fuel ethanol after 25 years. *Trends in Biotechnology*, 17(12), pp.482-487.

Ali Mekouar, M. (2011). 15. United Nations Food and Agriculture Organization (FAO). *Yearbook of International Environmental Law*, 22(1), pp.640-650.

Eriksson, M. And Spångberg, J. (2017). Carbon footprint and energy use of food waste management options for fresh fruit and vegetables from supermarkets. *Waste Management*, 60, pp.786-799.

Azad, A., Yesmin, N., Sarker, S., Sattar, A. And Karim, R. (2014). Optimum Conditions for Bioethanol Production from Potato of Bangladesh. *Advances in Bioscience and Biotechnology*, 05(06), pp.501-507.

Balat, M., H. Balat, and C. Oz. 2008. Progress in bioethanol processing. Progress in Energy and Combustion Science 34: 551-573.

De Oliveria M.E.D, B.E. Vaughan, and Jr. E.J. Riykiel. 2005. Ethanol as fuel: energy, Carbon dioxide balances, and ecological footprint. Bioscience 55: 593-602.

EIA. 2008b. Renewable energy sources & alternatives. Available at: Http://www.eia.doe.gov/fuelrenewable.html Accessed 4 December 2008.

Das Neves, L.C.M., A. Converti, T.C.V. Penna. 2009. Biogas Production: New trends for Alternative energy sources in rural and urban zones. Chem. Eng. Technology 32(8):1147-1153.

Refaat, A. A. 2010. Different techniques for the production of biodiesel from waste Vegetable oil. Int. J. Environ. Sci. Tech. 7 (1):183-213.

Korus, R.A., Hoffman, D.S., Bam, N., Peterson, C.L., D.C. Drown, 1993. Transesterification process to manufacture ethyl ester of rape oil. In: The Proceedings of the First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry, vol. II. National Renewable Energy Laboratory, Golden Co., pp. 815–826.

Shakhashiri, B.Z. 2009. Chemical of the week: Ethanol. Available at:

Http://scifun.chem.wisc.edu/CHEMWEEK/PDF/Ethanol.pdf Accessed on
February 2010.

Shuler, M.L., and F. Kargi. 2008. Bio press Engineering. 2nd ed. Prentice Hall PTR.
Kunz, M. 2008. Bioethanol: Experiences from running plants, optimization and prospects. Biocatalysts and Biotransformation 26(1-2): 128-132.

Lee, B., A.L. Pometto III, A. Demirci, P.N. Hinz. 1998. Media evaluation for the Production of microbial enzymes. Journal of Agricultural and Food Chemistry. 46(11):4775-4778.

Eksteen, J. M., P. Van Rensburg, R.R. Cordero Otero, and I.S.Pretirus. 2003. Starch Fermentation by recombinant Saccharomyces cerevisiae and glucoamylase genes From Lipomyces kononenkoae and Saccharomycopsis fibuligera. Biotechnology And Bioengineering 84-6.

Tasic M.B., B.V. Konstantinovic, M. L. Lazic, V.B. Veljkovic, 2009. The acid hydrolysis Of potato tuber mash in bioethanol production. Biochemical Engineering Journal 43: 208-211.

Abouzied, M., and C. A., Reddy. 1986. Direct fermentation of potato starch ethanol by Co-cultures of Aspergillus niger and Saccharomyces cerevisiae. Applied and Environmental Microbiology 52(5): 1055-1059.

Madson, P.W., D. A. Monceaux. 1995. Fuel ethanol production. In: Lyons, T.P., Kelsall, D.R. Murtagh, J.E. (Eds.), the Alcohol Textbook, Nottingham University Press, Pp. 257-268.

Bbs.gov.bd. (2019). *বাংলাদেশ পরিসংখ্যান ব্যুরো.* [Online] Available at: http://www.bbs.gov.bd/site/page/3e838eb6-30a2-4709-be85-40484b0c16c6/%E0%A6%95%E0%A7%83%E0%A6%B7%E0%A6%BF-%E0%A6%AA%E0%A6%B0%E0%A6%BF%E0%A6%B8%E0%A6%82%E0%A6%96%E0%A7%8D%E0%A6%AF%E0%A6%BE%E0%A6%A8-%E0%A6%AC%E0%A6%B0%E0%A7%8D%E0%A6%B7%E0%A6%97%E0%A7%8D%E0%A6%B0%E0%A6%A8%E0%A7%8D%E0%A6%A5 [Accessed 9 Aug. 2019].

Opentextbc.ca. (2019). Storage Temperatures and Procedures – Food Safety, Sanitation, and Personal Hygiene. [Online] Available at: https://opentextbc.ca/foodsafety/chapter/storage-temperatures-and-procedures/ [Accessed 9 Aug. 2019].

Zhu, Z. And Guo, W. (2017). Frequency, moisture content, and temperature dependent dielectric properties of potato starch related to drying with radio-frequency/microwave energy. *Scientific Reports*, 7(1).

Jiménez-Islas, D., Paez-Lerma, J., Soto-Cruz, N. And Gracida-Rodríguez, J. (2014). Modelling of Ethanol Production from Red Beet Juice by Saccharomyces cerevisiae under Thermal and Acid Stress Conditions. *Food Technology and Biotechnology*, [online] 52(1).

Najafpour, G. (2007). *Biochemical engineering and biotechnology*. Amsterdam: Elsevier.

Cheng, K. (2015). Conceptual design of an industrial-scale plant for ethanol production from byproducts of sweet potato processing. *International Journal of Biotechnology and Bioengineering*, 1(1), pp.01-08.

NOMENCLATURE

Symbol	Meaning	Unit
μ_{max}	Maximum Specific growth rate	(h^{-1})
$Y_{x/s}$	Biomass yield factor	(g/g)
K_s	Inhibition constant	(g/L)
$Y_{p/s}$	Product yield factor respect to substrate	(g/g)
X_m	Maximum Biomass Concentration	(g/L)
X_0	Initial Biomass Concentration	(g/L)
S_0	Initial Substrate Concentration	(g/L)
P_0	Initial Product Concentration	(g/L)
X_1	Biomass Concentration leaving the continuous aerobic fermenter	(g/L)
S_1	Substrate Concentration leaving the continuous aerobic fermenter	(g/L)
D_1	Dilution rate for the aerobic fermenter	(h^{-1})
M_1	Specific growth rate in continuous aerobic fermenter	(h^{-1})
F	Flow Rate	(L/h)
$P_{ethanol}$	Density of Ethanol	(g/L)
P_2	Final Product Concentration	(g/L)
V_w	Working volume of continuous fermenter	(m^3)
D_2	Dilution rate for the anaerobic fermenter	(h^{-1})
D_c	Diameter of fermenter	(m)
H_c	Height of fermenter	(m)
A	Growth associated constant	Dimensionless
X_2	Final Biomass concentration	(g/L)
$Y_{p/x}$	Product yield factor respect to biomass	(g/g)
μ_2	Specific growth rate in anaerobic fermenter	(h^{-1})
S_2	Final Substrate Concentration	(g/L)

t_{exp}	Exponential growth time	(h)
V_T	Total volume of batch fermenter	(m^3)
D_b	Diameter of batch fermenter	(m)
OUR	Oxygen Uptake Rate	(O_2/L/h)
Q_{O_2}	Oxygen transfer rate	(O_2/L/h)
M	Mole number of oxygen	Dimensionless
M	Molecular mass for oxygen	Dimensionless
Re_i	Reynolds number for impeller.	Dimensionless
N	Impeller speed	(rpm)
D_i	Impeller Diameter	(m)
μ	Dynamic Viscosity	(Nsm^{-2})
P_{no}	Power number for impeller	Dimensionless
P_g	Batch/continuous fermenter power	Dimensionless
N	Filtration speed	(rpm)
ΔP	Pressure difference	(Nm^{-2})