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Bio-ethanol Development from Domestic Waste

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Abstract

Climate change driven by carbon emissions from power plants using coal, gas, and oil is a major concern. Renewable energy sources like water, wind, solar, and biomass can help reduce pollution. This project explores using domestic waste to produce bio-ethanol, which can replace fossil fuels for electricity generation. The project addresses the depletion of natural resources and waste management challenges. By assessing corn and rice as alternatives to fossil fuels and developing a process to convert domestic waste into bio-ethanol, the project aims to provide a sustainable energy solution. Methods include drying, blending, fermentation, and distillation. Results show that corn and rice are viable alternatives, and a sustainable bio-ethanol production process was developed. This method can reduce pollution and promote renewable energy use. In conclusion, producing bio-ethanol from domestic waste can support sustainable power generation, aligning with the global shift toward cleaner energy.

1. Introduction

In recent years, the awareness of climate change and its impacts has significantly increased. One of the primary drivers of climate change is carbon dioxide emissions from power plants that rely on non-renewable natural resources such as coal, natural gas, and petroleum. These emissions contribute to altering weather patterns, raising global temperatures, and changing rainfall distributions [1]. While climate change can occur naturally, human activities like industrialization and deforestation have accelerated its progression. As a result, there is an urgent need to adopt cleaner and more sustainable energy sources to mitigate environmental damage.

Technological advancements have paved the way for generating electricity using renewable resources such as water, wind, solar power, and biomass from waste materials. These alternative energy sources offer a promising solution to reduce pollution and combat climate change. This paper focuses on utilizing biomass, specifically domestic waste, to produce electricity through the extraction of ethanol. The ethanol can be used to generate heat, which in turn can be harnessed to boil water for electricity production. By replacing traditional fossil fuels with ethanol, it is possible to produce electricity from heat energy in a more sustainable manner.

This project aligns with the global shift towards cleaner and more sustainable energy sources. Conducting feasibility studies and seeking expert guidance are essential steps to ensure the project's success and potential environmental benefits. Through the innovative use of biomass and ethanol, this project aims to contribute to a more sustainable energy future. Figure 1 shows the bioethanol production base on agricultural wastes.

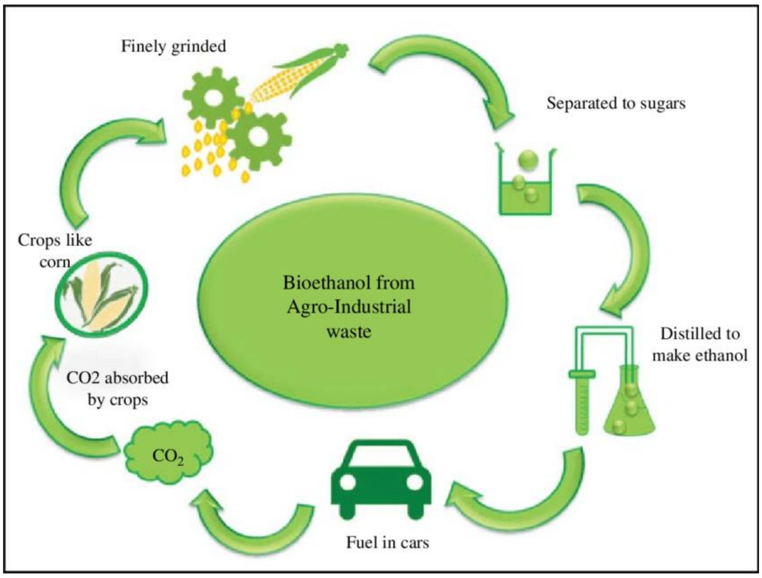


Fig. 1.1 The Bioethanol Production Cycle from Agro-Industrial Waste.

The issue of natural resource depletion, including coal, natural gas, and oil, is worsening day by day. These resources are extensively used worldwide, serving as primary sources in power plants for electricity generation, fueling internal combustion engines in the automotive industry, and contributing to the development of battery packs for electric vehicles. For example, energy from coal, a nonrenewable fossil fuel, has various drawbacks. Most high-quality coal is utilized, leaving lower-quality coal with greater moisture and ash. Power plant coal burning affects the environment and releases climate-changing carbon dioxide [2].

The domestic waste management industry faces significant challenges, requiring a substantial budget to process or decompose the increasing amount of waste generated each year. For the example, each person in Kuala Lumpur produces 0.8 to 1.3 kg of household waste every day, generating 3,500 tons. Organic garbage accounts for half. Solid waste is rising worldwide, especially in emerging nations. Global population growth increases trash output, which reached 318 million tons in 2000 [3]. This industry also necessitates the creation of numerous landfills to accumulate waste before the decomposition process can proceed. However, the practice of burying waste poses risks, leading to soil pollution and potential dangers to people.

Although there is a common association between pollution and the utilization of natural resources like coal, natural gas, and petroleum, it is critical to emphasize that pollution originates from anthropogenic activities such as their extraction, processing, and combustion. The combustion of fossil fuels leads to respiratory issues due to the inhalation of little airborne particles. This involves examining the composition and quantities of metals present in the pollution, their sources, and the detrimental health impacts they have, as determined by scientific research [4]. Fossil fuels, such as natural resources like petroleum and coal, have been extensively utilized for energy generation throughout the last century. Although petroleum, natural gas, and coal are natural resources, the manner in which they are extracted, processed, and utilized by humans contributes to environmental issues. It is essential to transition to more sustainable and environmentally friendly energy sources in order to reduce pollution and its negative impacts on human health and the environment.

2. Literature Review

2.1 Renewable Energy

Renewable energy refers to energy obtained from natural sources that are renewed at a faster rate than they are used. Sunlight and wind, for instance, are renewable sources that are continuously supplied. Renewable energy sources are abundant and omnipresent. Conversely, fossil fuels such as coal, oil, and gas are finite resources that require hundreds of millions of years to develop. When fossil fuels are combusted for energy generation, they release detrimental greenhouse gases, including carbon dioxide.

Biomass is the term used to describe organic matter that comes from living or recently living creatures and can be utilized as a sustainable source of energy. The materials encompassed in this category are diverse, ranging from wood, agricultural crops, animal manure, to organic waste originating from households, industry, and forestry. Biomass can be harnessed through several means to generate energy. Biomass energy is an important component of the worldwide energy system, providing a flexible and sustainable substitute for fossil fuels when handled in a responsible manner. The term "biomass" refers to a type of organic material that is generated from both plants and animals. Through the process of photosynthesis, plants are able to store the chemical energy that they get from the sun. This energy is stored in biomass. Through a variety of procedures, biomass can be transformed into liquid and gaseous fuels, or it can be burned directly for the purpose of producing heat. Bio-oil shows promise as an environmentally benign fuel alternative to fossil fuels, as it has the ability to minimize environmental harm and may be used in a wide range of applications. The International Energy Agency predicts that there will be a 28% surge in biofuel consumption, equivalent to 41 billion litres, from 2021 to 2026 [5].

2.2 Biomass

Biomass is a versatile and sustainable energy source derived from organic materials such as plant wastes, animal waste, and other biological matter. It has the capability to be transformed into several types of energy, including heat, electricity, and biofuels, using various techniques. Utilizing the process of direct combustion, biomass materials such as wood and agricultural leftovers can be efficiently converted into heat and power. Anaerobic digestion is a process that decomposes organic waste without the presence of oxygen, resulting in the production of biogas. This biogas can be utilized for heating or generating energy. In addition, biomass can be converted into liquid biofuels, such as ethanol and biodiesel, which can be used as substitutes for petrol and diesel in transportation. Biomass is deemed to be virtually carbon neutral due to the approximate balance between the carbon dioxide released during its combustion and the amount absorbed by the plants throughout their growth. The advantages of biomass energy encompass the reduction of reliance on fossil fuels, efficient management of waste, and improved energy security. Nevertheless, it is crucial to tackle issues such as the competition for land usage in biomass production, the potential release of particulates and other pollutants, and the effectiveness of conversion processes in order to guarantee the sustainable and eco-friendly utilization of biomass. Therefore, biomass energy is essential in the worldwide shift towards sustainable and renewable energy solutions, aiding in environmental preservation and the expansion of energy sources [6].

2.3 Residual Biomass

Residual biomass encompasses organic matter that remains after agricultural, forestry, and industrial activities. This encompasses agricultural byproducts such as straw and husks, forestry byproducts like wood chips and sawdust, trash generated from food manufacturing, as well as animal manure and sewage sludge. These materials, typically regarded as trash, can be transformed into useful resources such as bioenergy, biofuels, and bioproducts using various conversion procedures including combustion, gasification, anaerobic digestion, and fermentation. Utilizing leftover biomass not only aids in efficient waste management but also aids in the reduction of greenhouse gas emissions by substituting fossil fuels with renewable energy sources. For example, agricultural residues can undergo processing to generate bioenergy, resulting in a substantial reduction in the carbon footprint of energy production and promoting a more sustainable energy system [7].

Nevertheless, the effective utilization of residual biomass necessitates overcoming many obstacles. The heterogeneity in the content of biomass can impact the effectiveness and uniformity of energy generation processes. Advanced conversion methods are frequently required to manage diverse forms of biomass and optimize energy output. Furthermore, it is crucial to take into account the economic viability of these procedures, as the expenses associated with gathering, transporting, and treating biomass can be substantial. It is essential to include these methods into a circular bioeconomy to guarantee the sustainable utilization of leftover biomass, which will simultaneously enhance environmental advantages and contribute to economic and social objectives. Residual biomass can have a substantial impact on promoting renewable energy and developing a more sustainable and resilient energy infrastructure by establishing closed-loop systems that continuously transform waste into profitable goods [8].

2.4 Fermentation

Fermentation is a metabolic process where microorganisms, like bacteria, yeast, or fungi, transform organic chemicals into simpler ones, usually without oxygen. This change is facilitated by biological reactions that decompose intricate molecules into simpler compounds, thereby liberating energy. An easily recognizable instance of fermentation is the process in which yeast converts carbohydrates into alcohol and carbon dioxide during the manufacturing of alcoholic beverages such as beer and wine.

Fermentation processes in foods frequently result in modifications to the nutritional and biochemical quality of the original constituents. Fermented foods are composed of intricate ecosystems that are characterized by enzymes derived from basic ingredients that interact with the metabolic activities of the fermenting microorganisms. Fermenting microorganisms offer a distinctive method of ensuring the stability of food by causing physical and biochemical changes in fermented foods. In comparison to basic foods, these fermented foods can provide consumers with advantages in terms of antioxidants, peptide production, organoleptic and probiotic properties, and antimicrobial activity. It also contributes to the reduction of antinutrients and contaminants. The quality and quantity of microbial communities in fermented foods are contingent upon the manufacturing process and storage conditions/durability. This review enhances the current body of research on the biochemical transformations that occur during the fermentation of foods. The primary emphasis will be on the modifications to the biochemical compounds that determine the characteristics of the final fermented food products derived from the original food resources [9].

2.4.1 Alcohol or Ethanol Fermentation

Saccharomyces and other yeasts utilize a process known as alcoholic fermentation to extract energy from food when oxygen is insufficient. This process is analogous to the manner in which our muscles generate energy when we engage in vigorous exercise. During the process of alcoholic fermentation, yeast converts sucrose from the food to carbon dioxide and alcohol. This process occurs in two stages: initially, yeast converts sucrose to acetaldehyde, which it then converts to alcohol. When yeast performs this action in bread dough, it generates minute droplets of carbon dioxide, which induces the dough to expand. This is the reason why bread becomes tender and fluffy. Alcoholic fermentation is also responsible for the conversion of grape liquid into wine.

Organisms such as bacteria or yeast have the ability to utilize glucose, a sugar, in three primary ways: converting it into their own body material (biomass), utilizing it for fundamental energy to sustain their existence, or converting it into other substances that they require. Oxygen is required for the conversion of glucose into biomass. The quantity of oxygen necessary is contingent upon the amount of glucose that the organism is generating. The net oxygen requirement is determined by the difference between the oxygen required to consume the biomass and the oxygen required to burn the glucose itself if the glucose is being converted into biomass. This distinction aids in comprehending the quantity of oxygen required for the organism to develop and reproduce by utilizing the glucose it consumes [10].

2.5 Distillation

Distillation is a method employed to separate mixtures of liquids by taking advantage of their distinct boiling points. Picture yourself with a blend of two liquids, such as water and alcohol. These liquids exhibit varying boiling points, resulting in their conversion into vapor at distinct temperatures. During distillation, the mixture is subjected to heat until one of the liquids undergoes vaporization, while the other remains in its liquid state due to its higher boiling point. The vapor is subsequently cooled and condensed, resulting in the formation of a liquid that is collected in a separate container. This process efficiently separates the two liquids, enabling the purification or concentration of desired substances. Distillation is widely employed in a range of industries, such as the manufacturing of alcoholic beverages, essential oils, and petroleum refining, as well as in laboratory settings for the purification of chemicals. Most distillation methods in industry and lab research are variations of simple distillation. This process involves heating a liquid in a container (still or retort), cooling the resulting vapor in a condenser, and collecting the condensed liquid (distillate) in a receiver. The liquid with the lowest boiling point evaporates first. Simple distillation works well for purifying a liquid from nonvolatile substances and for separating liquids with very different boiling points. In labs, the equipment is usually made of glass and connected with corks, rubber bungs, or ground-glass joints [11].

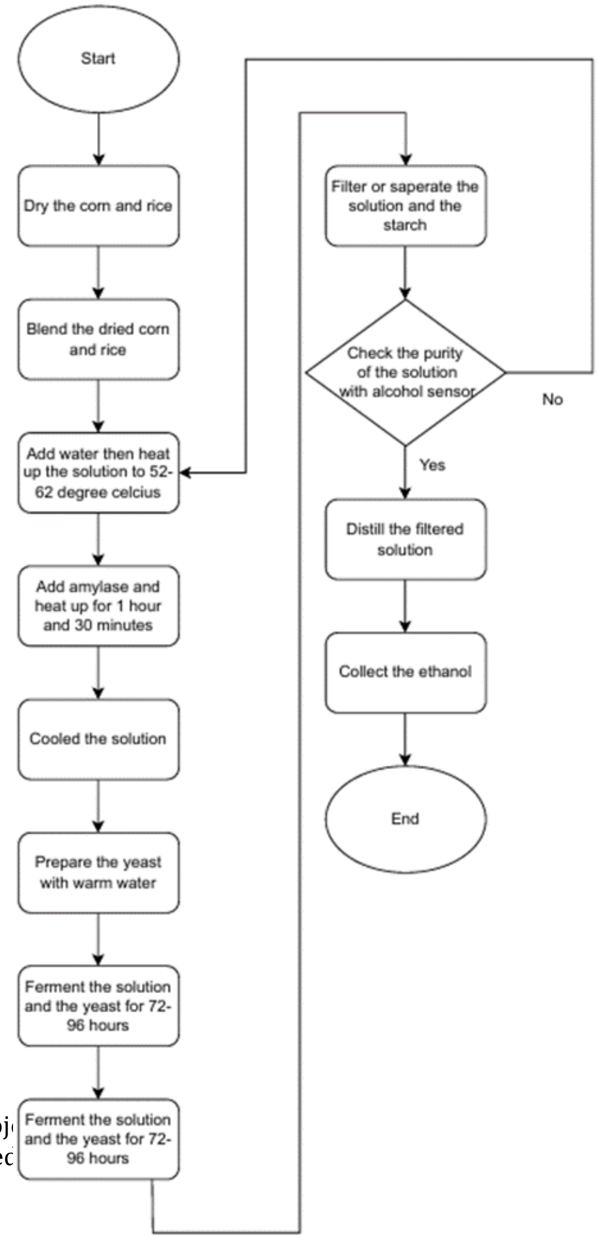
2.5.1 Fractional distillation

Simple distillation struggles to significantly purify mixtures when the boiling points of the components are close to each other. In simple distillation, the distillate is always richer in the component with the lower boiling point. Each vaporization-condensation step, called a "theoretical plate," acts like a mini distillation, making the distillate progressively richer in the lower boiling component. The effectiveness of a distillation process depends on the fractionating column used, which varies in surface area and the number of theoretical plates. These columns also differ in how much compound they retain due to wetting.

Fractional distillation, unlike simple distillation, is more effective for separating mixtures with close boiling points. It is widely used in oil refineries to divide the complex mixture into fractions with similar boiling points and properties, producing products like gasoline, diesel fuel, kerosene, and jet fuel. The choice of column depends on the specific separation task and availability. Understanding the differences between simple and fractional distillation is important, especially for those who have previously performed simple distillation and need to know how fractional distillation enhances the separation process.

3. Methodology

3.1 Flowchart



The flowchart illustrates the proj ls to ensure the project's success. Decision points that neec e product and byproduct are depicted in the flowchart.

3.2 Drying

The process of drying raw material for ethanol production is a crucial step in the overall ethanol production chain. Corn and rice as a feedstock, needs to be dried to a specific moisture content before it can be efficiently processed into ethanol. Efficient drying of raw material is crucial to the overall efficiency of the ethanol production process, ensuring optimal yield and quality of the final ethanol product. The raw materials will undergo a drying process, which can be achieved using two methods: either by using a dehydrator machine or by exposure to sunlight. This process is crucial because the raw material needs to be dry before proceeding to the grinding process. The drying process aims to remove the moisture from the raw materials, enhancing the efficiency of ethanol production.

3.3 Grinding

The milling or grinding process in ethanol development is a step that involves breaking down the raw material, corn, potato peel, and rice into smaller particles to facilitate the subsequent conversion of starches into fermentable sugars during the ethanol production process. The milling process is a critical component of ethanol development as it influences the efficiency of subsequent steps in the production chain. The goal is to achieve an optimal particle size that allows for effective conversion of starches to sugars during the subsequent stages of fermentation and distillation. The grinding process is one of the crucial steps in ethanol development because the dried raw material needs to be ground to an exact size. The size of the raw materials will affect the efficiency of the fermentation and distillation processes. The raw material can be ground using a blender or other machines capable of reducing it into small particles.

3.4 Fermentation

Fermentation is a key step in the production of ethanol from corn. During this process, microorganisms, typically yeast, are used to convert sugars derived from corn starch into ethanol and methyl gas. The fermentation process is a critical stage in ethanol production, as it determines the yield and quality of the final ethanol product. Efficient fermentation conditions, careful monitoring, and optimal yeast performance are essential for achieving high ethanol concentrations and maximizing the overall process efficiency.

The fermentation process is a crucial step that will determine the success of the project. For this process, water and ground raw materials are combined to create a solution. The solution is heated until it reaches 52-62°C to bring out the starch and glucose. Enzymes are then added to facilitate the appearance of sugar and starch. After the heating process, the solution needs to cool down to room temperature.

Once the solution is cooled, yeast is added to initiate the fermentation process. The yeast must be activated by adding water at a temperature around 30-35°C to optimize yeast activity. It's crucial to avoid excessively high temperatures, as they can lead to the death of the yeast. The activated yeast solution is then added to the starch solution to kickstart the fermentation process.

Fermentation takes place for 72-96 hours or more to produce ethanol. The fermentation process needs to be conducted in airtight containers to prevent interference from other processes. An airlock is used to maintain air-tight conditions during fermentation. Throughout the fermentation process, methyl gas and ethanol are produced.

3.5 Distillation

Fractional distillation is a crucial process in the production of ethanol from waste. After fermentation, the resulting mixture contains ethanol along with water and other impurities. Fractional distillation is employed to separate and concentrate the ethanol, producing a high-purity ethanol product. The fractional distillation process is fundamental in obtaining high-purity ethanol from the fermented mixture. It allows for the separation of ethanol from water and other components based on their different boiling points, resulting in a concentrated and purified ethanol product. After the fermentation process is complete, the distillation process needs to proceed to distill the ethanol from the solution. The fermented solution will be filled into the distillation flask. The distillation flask is wrapped in aluminum foil and soaked in paraffin oil to achieve the optimum temperature for the distillation process. The condenser with a cooling system will facilitate the easy collection of ethanol in the container. The solution needs to be heated to 79°C to obtain the optimum amount of distilled ethanol. After a certain duration, the ethanol will be gathered in the container.
this study.

4. Result and Discussion

4.1 Drying Process

The drying process has been carried out for each type of waste, with all waste being dried under the sun for the same period. The drying period for each waste lasted for two weeks. The weight of the wastes was recorded before and after drying. The weight losses of the wastes were calculated and recorded in Table 4.1.

Table. 4.1 Weight of wastes and the losses.

Waste	Before dry(g)	After Dry(g)	Losses (%)
Corn	1350g	437g	67.63%
Rice	1200g	418g	65.16%

The weight of the corn is 1350 g, and after drying, the weight of the dried corn is 437 g. The weight loss of the corn is 67.63%. The weight of the rice is 1200 g, and after drying, the weight of the dried rice is 416 g. The weight loss of the rice is 65.16%. Figure 4.1 shows the drying result of corn and rice.

Fig. 4.1 Corn and Rice Dry Result.

4.2 Blend process

The blending process is the second step involved in this project. The dried wastes need to be blended to ensure they can react with amylase during the hydrolysis process to break down the complex sugars in the wastes. The waste will be weighed before and after the blending process. The data on the weight of the wastes have been recorded in Table 4.2.

Table 4.2: Weight of wastes before and after being blended.

Dried waste	Before blend (g)	After blend (g)	Losses (%)
Dried corn	437g	434g	0.69%
Dried rice	418g	416g	0.48%

The weights of the dried wastes after blending were recorded. This process resulted in some losses due to errors and waste being stuck in the blender. The weight of the dried corn before blending was 437 g, and after blending, it was 434 g. The loss of the dried corn after this process is 0.69%. The weight of the rice was 418 g before blending, and after blending, it was 416 g. The loss of the dried rice is 0.48%. Figure 4.2 shows the blend result of corn and rice.

Fig. 4.2 Corn and Rice Blend Result.

4.3 Hydrolysis Process

The hydrolysis process involves heating the blended dried wastes with water. The main purpose of this process is to break down the complex sugars in the dried wastes. This process also involves the use of amylase, an enzyme that helps to break down the complex sugars in the wastes. The weight of the wastes used in this process is 50 grams. The solution is heated to 50 degrees Celsius, and amylase is added to facilitate the breakdown of complex sugars. Amylase remains active between 52 and 62 degrees Celsius. Stirring is necessary to ensure optimal heat distribution and uniform temperature throughout the solution. Each solution receives 3 grams of amylase. The recorded data, showing temperature changes every 10 minutes during the process, is presented in Table 4.3.

Table 4.3: Temperature of solution in every 10 minutes.

Mixture / Time (min)	Corn mixture temperature (°C)	Rice mixture temperature (°C)
10 min	52 (°C)	52 (°C)
20 min	55 (°C)	54 (°C)
30 min	57 (°C)	56 (°C)
40 min	57 (°C)	57 (°C)
50 min	60 (°C)	58 (°C)
60 min	57 (°C)	57 (°C)
70 min	54 (°C)	57 (°C)
80 min	53 (°C)	56 (°C)
90 min	50 (°C)	54 (°C)

Controlling the corn mixture solution is easier compared to the rice solution. The temperature of the corn solution increases and decreases proportionally, facilitating better control. Besides, the temperature of the rice solution fluctuates irregularly, making it more difficult to manage. It is essential to maintain control over the solutions because the optimal temperature range for amylase activity is between 52 and 62 degrees Celsius. Figure 4.3 shows the hydrolysis process.

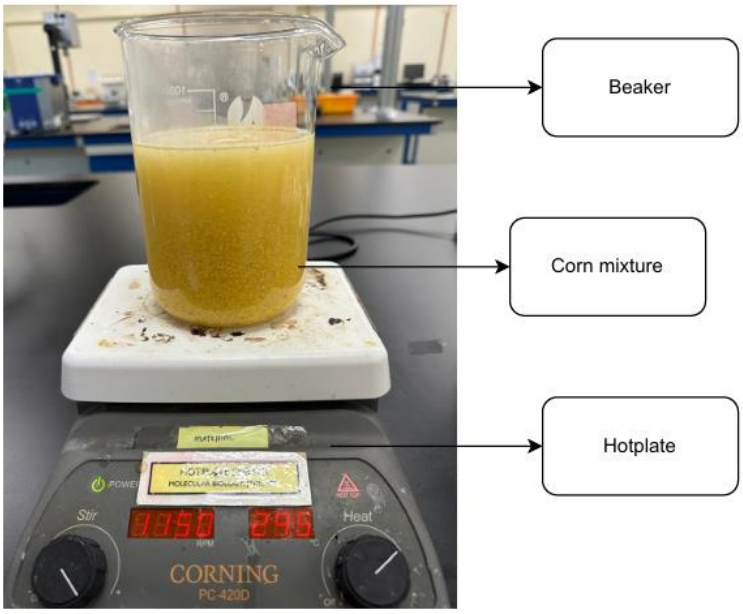


Fig. 4.3 Corn Hydrolysis Process.

4.4 Fermentation Process

The hydrolysis process is the process before the fermentation process. During fermentation, the mixture is cooled before adding the yeast solution to the mixture solution. Fermentation takes place in a fermentation vessel equipped with an S-type airlock. This fermentation process is anaerobic, meaning oxygen cannot be involved. It results in the production of simple sugars and alcohol. Two grams of yeast are used in this process. Yeast is a tiny organism used in fermentation. It works with an enzyme called amylase to break down sugars and produce ethanol) and a gas called methane.

Before initiating the fermentation process in the waste mixture solution, yeast undergoes preparation by first being weighed and then activated with warm water between 30 to 35 degrees Celsius. After resting for 15 minutes, the yeast is stirred and combined with the waste mixture solution. During fermentation, two distinct layers form: the fermentation solution and fermentation grains. Table 4.4 provides data regarding the weights of waste, enzyme, and medium used in this fermentation process.

Table 4.4: Fermentation wastes and medium.

Waste powder (g)	Enzyme (g)	Medium (g)
Corn powder (50g)	Amylase (3g)	Yeast (2g)
Rice powder (50g)	Amylase (3g)	Yeast (2g)

When comparing corn fermentation to rice fermentation, corn fermentation produces more methane gas. This is seen in the number of bubbles released during the process; corn grains release more bubbles than rice grains. The reason for this difference lies in the reaction between yeast and amylase, which is more intense in corn fermentation. In corn, yeast and amylase work together more efficiently to break down the starches, resulting in more gas production. On the other hand, rice fermentation releases fewer bubbles because the interaction between yeast and amylase is less vigorous. Therefore, less methane gas is produced. In summary, the fermentation of corn is more active and produces more gas compared to the fermentation of rice. Figure 4.4 shows the fermentation process.

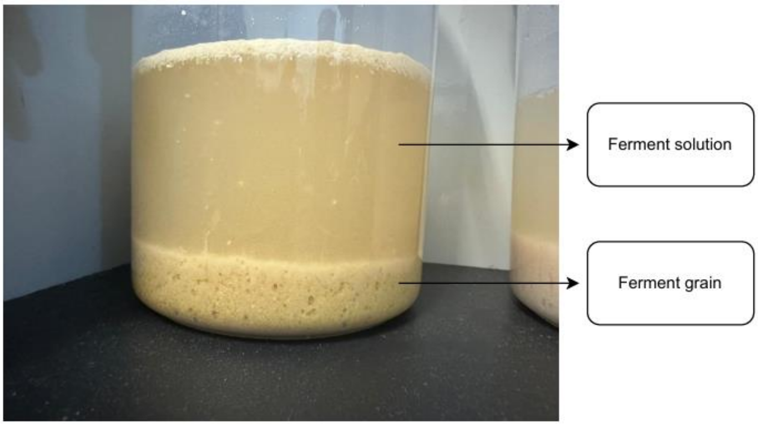


Fig. 4.4 Corn Fermentation Process.

4.5 Distillation process

The distillation process can only proceed when the solution contains less than 70% alcohol purity. To determine the alcohol purity, an alcohol sensor is utilized, resembling a thermometer but designed to float in the solution. When measuring the alcohol purity, the sensor is submerged, and the scale at the sensor indicates the purity level. If the alcohol purity is below the required threshold, the distillation process cannot proceed due to the low ethanol purity. Table 4.5 state the purity of the ethanol in corn and rice fermented solution.

Table 4.5: Ethanol purity.

Fermented solution	Ethanol purity
Corn solution	< 70%
Rice solution	< 70%

The fermented solution cannot achieve more than 70% ethanol purity because the amount of waste used in this project is too low. In the fermentation process, yeast and amylase work together to produce both methane gas and ethanol. However, when there isn't enough waste material, the reaction doesn't generate enough ethanol to reach a purity higher than 70%. Additionally, adding more waste to increase ethanol production is not an option for this project. The equipment used cannot handle more waste and water during the hydrolysis process, which would lead to project failure. Therefore, the limitation in waste quantity prevents achieving ethanol purity greater than 70%.

5. Conclusion

In conclusion, this project aimed to address the dual objectives of assessing the suitability of corn and rice as substitutes for natural resources in power plants and developing a sustainable process for converting domestic waste into bio-ethanol. Through a comprehensive analysis, it was determined that both corn and rice possess the necessary attributes to serve as viable alternatives, considering their availability and extraction processes. Additionally, a sustainable process for bio-ethanol production from domestic waste was successfully developed, encompassing waste selection, conversion optimization, and economic and environmental evaluations. This innovative approach holds promise for reducing pollution in power plant operations while promoting the efficient utilization of renewable resources. The project's findings underscore the potential for integrating bio-ethanol production from domestic waste into power plant operations as a viable strategy for sustainability and environmentally friendly.

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