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A Comparative Analysis of Pineapples *(Ananas Comosus)* from Different Bioethanol Sources Available in the Philippines

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Abstract:- Due to the oxidation of CO2, SO2, and NOX, a depletion of fossil fuels has been occurring which develops an environmental impact as time goes by. Bioethanol has grown in popularity not just as a chemical feedstock, an industrial solvent, or a beverage, but also as a vehicle fuel option in recent years. Thus, this study will introduce the feasibility of pineapples (*Ananas Comosus*) as an ethanol substrate in comparison with other documented feedstocks in the Philippines. The researchers will conduct an experiment that will introduce the feasibility of pineapples with the help of data gathered from past studies. The experiment will include major processes which are extraction, dilution, sugar adjustment, pH adjustment, chemical pasteurization, aerobic and anaerobic fermentation, siphoning, distillation, and observation days to come up with the desired data and be able to compare it with the other bioethanol produced. In addition to that, such guidance was sought by the Department of Science and Technology. Thus, the effectiveness and success of the experiment will help eliminate the contribution of pollution with the introduction of pineapple's bioethanol components and further avoid using fossil fuel. Within the comparative analysis made, future researchers can rely on the study made for a greener community we all aspire to have.

Keywords:- *Fermentation, Distillation, Bioethanol, Feedstocks.*

I. INTRODUCTION

With the climate change the Earth is continuously facing, the production and use of fossil fuels have played a big impact not just on the climate but also in terms of health and the economy. According to new research by Greenpeace Southeast Asia (2020), air pollution from fossil fuels can cause an estimated 27,000 premature deaths per year in the Philippines. In addition to that, the country can experience approximately 1.9% of Gross Domestic Product (GDP) in economic losses annually. Pollution from fossil fuels every year is taking millions of lives as it increases risks of strokes, lung cancer, and asthma, as well as trillions of dollars in economic losses. Filipinos have long been the victims of climate change, as well as the health and economic consequences of polluted air. The country must switch to renewable energy sources and phase out coal-fired power facilities (Yu, 2020) may work best in one situation while another may work best in a different situation (Reigeluth, 1999).

On January 12, 2007, the Biofuels Act of 2006 (RA No. 9367) was approved to support the development and utilization of sustainable energy resources with appropriate funds and programs. Moreover, this law mandates the Philippines to blend bioethanol into commercial gasoline in the country at 10% within four years of the law's effectiveness. As the year goes by, the Department of Energy (DOE) has projected the 10% blend to be raised to 20% from 2020 until 2030. Last 2020, the DOE also projected at least 15 additional ethanol plants to meet the needed blend requirement. Achieving the mandated blend for the country sparked a lot of researchers to push through biofuel studies as the provisions of this law offer a lot of support when it comes to bioethanol. On the contrary, the country is still facing issues regarding the mandated minimum percentage of blended bioethanol in all gasoline fuels. Moreover, according to Gatdula et al. (2020), the Philippines' bioethanol industry has insufficient feedstock availability and inefficiency in the whole process. With that, it has been more challenging for the Philippines to comply with the 10% mandated ethanol blend in gasoline.

Determining the potential of other crops to become another source of feedstock through a sugar analysis method, is recommended by a study of Ms. Kristel M. Gatdula, Mr. Rex B. Demafelis and Mr. Butch G. Bataller last 2020. In line with that, the researchers decided to conduct a study focusing on a comparative analysis of the existing crops containing ethanol content. In addition to that, the researchers plan to introduce pineapples (Ananas Comosus) as another source of feedstock and/or as an additive to gasoline blends. It is the goal of the study to contribute to additional ethanol plants and compare it to the existing ones to help bioethanol researchers and manufacturers to distinguish which crop will fit their sustainability criteria.

II. BACKGROUND OF THE STUDY

Air pollution has always been an issue in the Philippines. According to a World Health Organization research published in 2018, there were 45.3 air pollution-related deaths for every 100,000 inhabitants in the

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Philippines. It ranked third in the world, after only China's 81.5 pollution-related deaths per 100,000 people and Mongolia's 48.8 deaths per 100,000 people. And it seemed to be getting worse. Despite this, Filipinos prefer to dismiss the issue of air pollution. Coal-fired power stations generate the lion's share of air pollution in host regions in the Philippines, while automobile emissions are the biggest offender in the country's urban areas. According to the data of the Department of Environment and Natural Resources (DENR), vehicular sources account for 65% of air pollution in the country, primarily in Metro Manila. Air pollution is expected to increase given the projected 4.6% annual growth rate in energy demand (Mallari,2020). This demand corresponds to the projected growth in road vehicles to 24.8 million by 2030, up from 6.6 million in 2010.

Global energy consumption has increased 17-fold in the last century as a result of the burning of fossil fuels, primarily in the transportation sector, which generates primary atmospheric pollution. The emissions produced by fossil fuel combustion have the potential to harm human health. Carbon monoxide (CO) in high concentrations can be lethal to the heart and hurt the nervous system. Oxidation of CO can also significantly disrupt oxygen transport in the blood by generating carboxyhemoglobin. As a result, the researchers are aware to scrutinize and introduce another agricultural crop, pineapples, as another alternative bioethanol that is accessible in the Philippines. It is the objective of this study to lessen the use of fossil fuels for a more sustainable environment in the aviation industry.

Biofuels are a substitute for petroleum fuels. It can be used alone or blended together with petroleum (Demirbas 2002; Demirbas 2003). Biofuels give more benefits since they come from renewable resources. Its sustainability reduces greenhouse gas emissions, regional development, social structure, agriculture, and security supply (Demirbas 2006; Demirbas 2008; Unal and Alibas, 2007; Ikilic and Yucesu 2008). Benefitting from biofuels has been a long-term goal for everyone as climate issues continue to arise.

The use of ethanol replacing aviation gasoline has similar effects to the replacement of vehicular gasoline, such as an increase in average engine power of 7% and a reduction in autonomy of 25–40% due to its lower calorific value (28 MJ kg^{-1} vs. 43.5 MJ kg^{-1}) with higher economic benefits related to the higher cost of aviation gasoline, on average US$ 0.80 per liter, and environmental benefits as a renewable fuel, to reduce CO_2 emissions by up to 63% and with total absence of lead and sulfur (Baumi, et al., 2020). Moreover, according to the Air Transport Action Group, the civil aviation industry produced 781 million tonnes of carbon dioxide (CO_2) in 2015, or 2% of all anthropogenic greenhouse gas emissions (ATAG).

According to the study conducted by Baumi, et al. (2020), the sugar and ethanol industry was introduced in Brazil in the seventeenth century and evolved into one of the primary sources of bioenergy integrated into the national energy matrix in the twentieth century. Brazil was a pioneer in public policies for the use of biofuels in the 1970s, implementing laws requiring the addition of 10% ethanol to gasoline in 1973 and launching the Próalcool program in 1975, which aimed to partially replace gasoline with ethanol in the vehicle fleet in response to the first major global oil crisis.

According to a research study conducted by Lye (2020), when the cost of producing one liter of ethanol was calculated, it was pineapple (Ananas Comosus) that was the most cost-effective because of a store price less than Red-Apples. Moreover, Wandono et al. (2020) research study results showed that pineapple waste has 27% alcohol content in the first distillation and 12% cellulose content. Through cellulose content, the production of bioethanol is possible by transforming them into easily fermentable monosaccharides (simple sugars, such as glucose) by physical, chemical, and biological treatments, and then used as a fermentation substrate to produce ethanol through a fermentation process.

In the Philippines, cassava has for a long time primarily been cultivated for food and in smaller but increasing quantities, for animal feed and other industrial products. The crop is relatively typhoon and drought-resistant, and requires minimum crop maintenance. More recently, it has gained importance as a possible fuel commodity not only in the Philippines but also in China, Thailand, Indonesia, and other countries that have more advanced national biofuel programs (Ranola, Jr., et al. 2009). The size of the market for bioethanol and the competitiveness of cassava feedstock with other sources of feedstock are major considerations for tapping cassava as a possible source of bioethanol.

The Philippines has a huge potential for producing different crops such as sugarcane, corn, sweet sorghum, and cassava which are suitable sources of feedstock for bioethanol production (Ranola, Jr., et al. 2009). Only sugarcane, on the other hand, can provide a locally sustainable source of ethanol for vehicle fuel. Ethanol produced from sugarcane feedstock is the main competitor of ethanol produced by the projected cassava feedstock project. Sugarcane bagasse can be used as a renewable fuel source for the distillery's boilers, reducing the need for bunker oil. Ethanol from overcapacity distilleries and cheaper ethanol from other countries are possible competitors for ethanol produced from cassava feedstock.

Pineapple, Cassava, and Sugarcane have been recorded as the most abundant crops in the Philippines. Within the year 2019, the Philippine Statistics Authority recorded a total volume of 2,630,800.28 metric tons of production for cassava. Meanwhile, in the same year, sugarcane had a record of 20,719,291 tone's of production. In the case of pineapples, the Food and Agriculture Organization of the United Nations (FAO) has declared that the Philippines ranks second globally in total pineapple production as of 2019. This was because the record for pineapple production in 2019 was 2.74 million metric tons. With the abundance of these crops, extracting ethanol from them has come to light together with their chemical components. Comparing the three will enable the researchers to introduce pineapples as another source of ethanol to help the country reach the mandated ethanol blend.

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As to the knowledge of the researchers, studies on pineapples as a bioethanol substrate have been conducted but only limited to its waste and not the whole pineapple itself. With that, the researchers will contribute to the bioethanol research and development by extracting ethanol content from whole rotten pineapple including the peels, leaving no waste from it. The researchers then decided to conduct this present study that will enable them to contribute to a solution to fossil fuel depletion and air pollution through bioethanol production in pineapples.

III. STATEMENT OF THE PROBLEM

The researchers believe that a pineapple is a good alternative feedstock as a bioethanol product. Moreover, the researchers will gather the potential ethanol component of pineapples as recorded data. With that, the researchers will analyze and compare the recorded data with other bioethanol substrates available in the Philippines such as sugarcane and cassava. Specifically, this study seeks to answer:

A. What are the Characteristics of Pineapple as a Good Complementary Feedstock in Utilizing Bioethanol Products in Terms of:

- *Ethanol Production Rate;*

- Distilled at 60 degrees;
- Distilled at 70 degrees?

- *Sugar/Sucrose Composition?*

B. What are the Differences Between Pineapples from other Cassava and Sugarcane Ethanol Production?

C. How Much Time did it Take to Gather the Bioethanol Component of the Pineapple, Cassava, Sugarcane in Terms of:

- *Gathering an Amount of Needed Crop;*

- *Fermentation;*

- *Distillation Process?*

Hypothesis

In addition to the previously stated questions, the study will also test the following research hypothesis:

- H01. The researchers found that the pineapple does not contain bioethanol upon extraction.
- H1. The researchers found that the pineapple contains bioethanol upon extraction.
- H02. There is no difference on pineapple and other agricultural crops containing bioethanol.
- H2. There is a difference on pineapple and other agricultural crops containing bioethanol.
- H03. Pineapple is not a good complementary alternative as a bioethanol product in terms of its ethanol production timeline.
- H3. Pineapple is a good complementary alternative as a bioethanol product in terms of its ethanol production timeline.

Significance of the Study

This study will be undertaken to figure out how much ethanol content Pineapple can produce and compare to available biomass in the Philippines such as cassava and sugarcane. Thus, the result of this study will benefit the following:

- **Future bioethanol researchers.** Future bioethanol researchers are part of the beneficiary as the study will introduce that pineapple is a viable alternate source of bioethanol compared to common biodiesel feedstock in the Philippines.
- **Future bioethanol manufacturers.** The study aids future bioethanol manufacturers in discovering how much ethanol can be obtained. This could also help in learning if pineapple will be a more profitable source of biofuel by lessening the cost of producing it.
- **Regular vehicle owners**. The study will benefit the regular vehicle owners on the usage of sustainable fuel that burns more cleanly and decrease the emission of carbon dioxide.
- **Aviation industry**. The study will benefit the aviation industry as to potentially decrease the high production cost of aviation kerosene that is not from the fossil fuel as to decrease the greenhouse emissions of the industry.
- **Researchers themselves**. The researchers themselves can showcase comparative data on ethanol yield from different plant species and how well it will perform as a biofuel.

Scope and Limitations of the Study

This probe of research mainly dwells on the comparative analysis of data and extraction of ethanol from pineapples (Ananas Comosus). Thus, this study aims to gather the ethanol component of pineapples as data to analyze and compare with other bioethanol substrates available in the Philippines such as sugarcane and cassava. With that, this study will be limited to the researchers alone. The limitation of the study will be focusing on bioethanol data as to introduce the potential of pineapples to be a source of feedstock alongside with the other crops to be compared.

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➢ *Conceptual Framework*

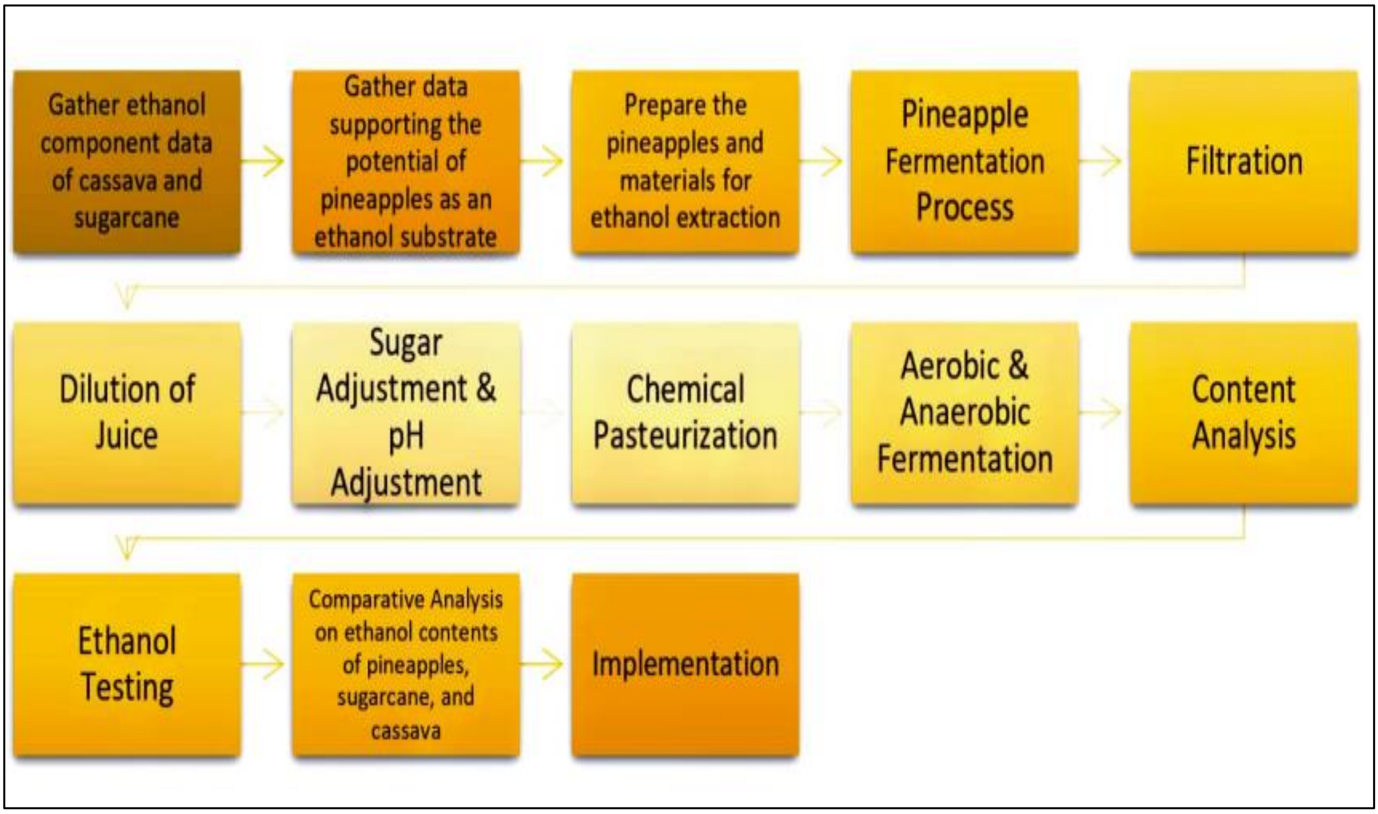

Fig 1: The Conceptual Framework of a Comparative Analysis of Pineapples (Ananas Comosus) from Different Bioethanol Sources Available inthe Philippines.

The figure above is a diagram of the comparative analysis that the researchers will conduct upon the gathering of data through a literature review and an experimental process. As seen from above, the variables of this study will start from gathering data on different literatures before the experimentation procedures proceed. The preparation of the pineapples and materials for filtration will take then take place to head start the experiment. Followed by the dilution of juice s done to control cell growth and product formation, and to maintain optimal conditions for the microorganisms involved in fermentation. The adjustments of its sugar/sucrose content and pH level will be next as another preparation done for the fermentation process. Before proceeding to the fermentation period, a chemical pasteurization will be done to kill unnecessary bacteria in the production of ethanol. The fermentation process will be classified into two. These are the aerobic and anaerobic fermentation. This procedure period is one of the important variables in every ethanol extraction procedures. The fermented pineapple will then undergo distillation to finally extract the ethanol contents in the pineapple juice. With that, ethanol testing will be the final step for the experimentation process of the study. In this step, the percentage of ethanol will be confirmed once the extracted ethanol successfully passes the moisture analysis. Implementation of the pineapples as ethanol substrate can then be conducted.

➢ *Theoretical Framework*

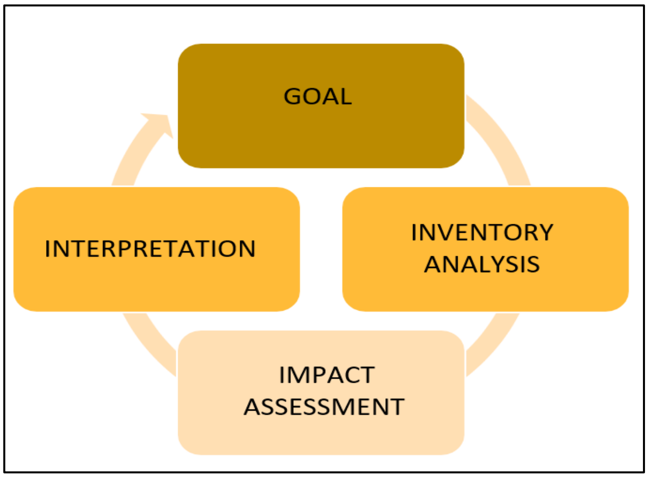

Fig 2: The Theoretical Framework of a Comparative Analysis of Pineapples (Ananas Comosus) from Different Bioethanol Sources Available inthe Philippines

In order to understand further the comparative analysis, the researchers will conduct, alongside the extraction of ethanol components from pineapples, this study will use the Life Cycle Assessment theory. Christoph Meinrenken defined this theory as a methodology to assess the environmental impact of products as an important tool in corporate sustainable management (Caba, 2017). This framework will guide the researchers on interpreting the

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gathered data throughout the study. This theory will support the comparative analysis of the study as a backbone on how an analysis should be made in relation to its environmental impact.

The figure above shows the interconnection of Christoph Meinrenken's Life Cycle Assessment theory with the interpretation of data. In this study, this framework will be utilized to understand the similarities, and differences, and how pineapples are a good complementary feedstock.

The goal as stated on the diagram is to know the differences and similarities between pineapple sugarcane and cassava. Moreover, pineapples as another alternative bioethanol that is accessible in the Philippines.

The inventory analysis on the diagram is where the literature review and experimentation will take place. This part will determine the ethanol and sugar/starch content of the cassava and sugarcane through a literature review. Meanwhile, the ethanol and sugar/starch content of the pineapples will be determined through the experiment to be conducted by the researchers.

The impact assessment phase will be the one emphasizing the importance of the study as it is related to the ethanol impact on the Philippines and climate change. With that, the comparison of the pineapples, cassava, and sugarcane will also take place in terms of their capabilities as a bioethanol substrate in the Philippines.

The interpretation is the last part as it will be the result of the study after the literature review and experimentation is accomplished for the comparative analysis. After the analysis, it will then interpret whether pineapples can be introduced as a new ethanol substrate and as an addition to the projected 15 plants of the Department of Energy to produce ethanol. This will be done after the differences and similarities are done to comprehend the potential of the pineapples.

IV. METHODS OF RESEARCH

The researchers will gather the data using experimental methods. This method will help determine the ethanol components of pineapples (Ananas Comosus) and record them to compare them with other crops such as sugarcane and cassava with ethanol contents. After gathering the data, the researchers will analyze it to be able to come up with the interpretation of data on whether pineapples are a better substrate of bioethanol than the other crops available in the Philippines.

➢ *Research Design*

This study will utilize both experimental research and comparative analysis of data. It aims to gather the ethanol component of pineapples as data to analyze and compare with other bioethanol substrates available in the Philippines such as sugarcane and cassava. This will allow the researchers to introduce pineapples to bioethanol researchers as another source of feedstock.

With the mandated 20 percent of ethanol mixtures to gasoline as of RA No. 9367, meeting the required ethanol blend has been hard for the Philippines due to different circumstances. This includes the lack of feedstock sources and the capability of plantations to produce the needed number of crops that will suffice the desired ethanol yield. Other than that, the production of bioethanol is facing competition over biomass power generation. Instead of creating more bioethanol, a lot of crops such as 68% of sugarcane bagasse would be used to meet the needed fuel for electricity and heat generation (Go et. al., 2020). With that, the researchers will introduce another potential source of feedstock to contribute to helping the projected 20% ethanol blend of the Department of Energy (DOE). This introduction will come with a comparative analysis of other sources of bioethanol present in the Philippines to distinguish the effectiveness of pineapples as a substrate.

➢ *Materials and Procedures*

The following listing/s are the materials that were used in the extraction of ethanol components in pineapples (Ananas Comosus):

Fig 3: Pineapple (Ananas comosus)

Pineapple, (Ananas comosus), perennial plant of the family Bromeliaceae and its edible fruit. Pineapple is native to tropical and subtropical countries and has been introduced elsewhere. Pineapple peels are rich in intracellular sugars and plant cell walls which are composed mainly of cellulose, pectic substances, and hemicelluloses.

Fig 4: Saccharomyces Cerevisiae (Yeast)

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Saccharomyces Cerevisiae is the common microbes employed in ethanol production due to its high ethanol productivity, high ethanol tolerance and ability of fermenting wide range of sugars (Azhar, M. et. al, 2017).

Fig 5: Natrium Hydroxide (NaOH)

Sodium hydroxide is also known as *lye* or *soda*, or *caustic soda.* At room temperature, sodium hydroxide is a white crystalline odorless solid that absorbs moisture from the air. In this study, it will be utilized to increase the desired pH level of the pineapple.


Fig 6: Hydrochloric Acid (HCl)

Hydrochloric acid, solution is a colorless watery liquid with a sharp, irritating odor. Consists of hydrogen chloride, a gas, dissolved in water. In this study, it will be utilized to decrease the desired pH level of the pineapple.


Fig 7: Distilled Water

Distilled water is steam that has been cooled and returned to liquid form from boiling water. By collecting steam from boiling water, salts, minerals, and other organic materials are removed. Distilled water will be used consistently in this study to pasteurize all apparatus before use. Distilled water will also be used as a solution mixture with the pineapple juice.

Fig 8: Potassium Metabisulfite (KSM)

Potassium Metabisulfite is a chemical that is used in chemical pasteurization. It is called a stabilizer in a fermentation process as it kills unnecessary bacteria present. With that, it prevents spoilage and further fermentation by removing oxygen.

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Fig 9: Diammonium Phosphate (DAP)

Diammonium Phosphate is utilized in the beginning of fermentation period which adds nutrients to the solution. In accordance to that, the nutrients it provides benefits the yeast metabolism.

Fig 10: Sugar

Sugar (Refined Sugar) is used in increasing the sugar/sucrose level of a solution in brix degrees. It is sucrose, a disaccharide, made up of two sugars (glucose and fructose) bound together, that is naturally made by and found in all green plants.


Fig 11: Volumetric Flask

Volumetric Flask is a laboratory apparatus that is mainly used to precisely measure volumes of liquid through a mark on its elongated neck. It is also used for holding and preparing solutions. In this study, it is used to help measure the sugar percentage of the diluted pineapple.


Fig 12: Beaker

Beaker is cylindrical, glass container with a flat bottom and a tiny pouring spout that is typically used in laboratory experiments to hold, heat, mix, and stir liquids, solutions, and other samples. a laboratory equipment used for measuring the solvents used.


Fig 13: Traditional Handheld Refractometer

Traditional Handheld Refractometer is an instrument used in measuring the sugar level in brix degrees. It is an analog instrument in which a drop of a sample can be measured with a help of a light and a sensor prism. In addition to that, it does not require a battery or power source.

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Fig 14: Digital Food Scale

A digital food scale is used to measure various quantities of food ingredients which provides measurements of weights to the nearest gram. It is intended to deliver quick measurements and precise readout.

Fig 15: Airlock

Airlock is a small pipe attached on the lid of the container. It is utilized in the fermentation process such as aerobic and anaerobic ones. It is a chamber like item with a passageway that helps the release of carbon dioxide and the passage of oxygen.

Fig 16: pH Meter

A pH meter is an electronic instrument used to obtain more accurate pH measurements. It particularly measures hydrogen ion activity in solutions, or the acidity/alkalinity of a solution.

Fig 17: Incubator

An incubator is a heated box with insulation to keep the temperature, humidity, and gaseous contents inside at optimal levels. It is used to cultivate microbiological or cell cultures.

Fig 18: Latex Gloves

Latex gloves are disposable personal protective equipment (PPE) usedin laboratories to protect your hands from contaminants and potentially harmful chemicals.

Fig 19: Cheese Cloth

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Cheese Cloth is a type of cloth used in filtering the juice and its residue. It is a lightweight cotton fabric with an open texture. "*Katsa*" is an alternative for this.

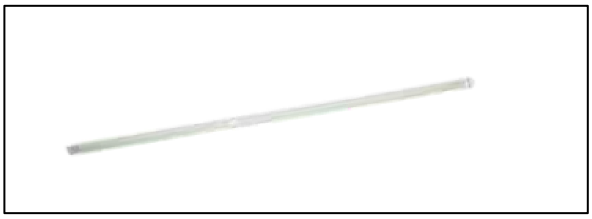

Fig 20: Glass Stirring Rod

Glass Stirring Rod is a laboratory equipment primarily used in mixing chemicals. It is made of a solid glass that is slightly longer than a drinking straw and has rounded ends.

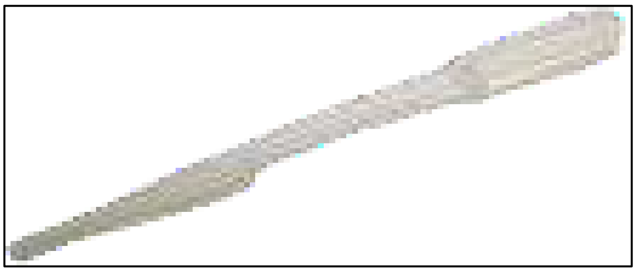

Fig 21: Dropper

A dropper is a type of pipette that consists of a small, plastic tube with a rubber, vacuum bulb at one end that draws liquid in and releases it one drop at a time. It is utilized in the sugar measurement on the Traditional Handheld Refractometer.

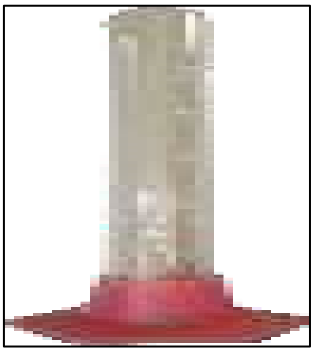

Fig 22: Graduated Cylinder

A graduated cylinder is a laboratory glassware used to measure the volume of a liquid. It has a cylindrical shape with markings on the side that indicate the volume of the liquid contained within. The markings are usually in milliliters or cubic centimeters.

Fig 23: Blender

A blender is an electric mixing device with sharp, rotating blades or paddles that is used to prepare food by liquefying, mixing, puréeing, and emulsifying substances. The pineapples were easily squeezed as they were blended first.

➢ *List of Equipment/Apparatus*

- Knife
- Blender
- Strainer
- Cheese cloth
- Volumetric Flask
- Graduated Cylinder
- Glass Stirrer
- 1000mL Schott Bottle
- 250mL Schott Bottle
- 1000mL Beaker
- "Katsa"
- Incubator
- Funnel

Table 1: List of Materials

Quantity:	Materials/Equipment	Price:	Total Price:
62	Pineapple	Php 40/50/60 each	Php 2510
2	Yeast (China)	Php 137	Php 274
2	Sodium Hydroxide	Php 100	Php 200
1	Yeast (LALVIN)	Php 108	Php 108
1	Hydrochloric Acid	Php 550	Php 550
2	Distilled Water	Php 78	Php 156
3	Cheese cloth	Php 77	Php 231
1	250 mL Schott Bottle	Php 276	Php 276
1	1000 mL Schott Bottle	Php 701	Php 701
1	1000 mL Beaker	Php 388	Php 388
2	Funnel	Php 10	Php 20

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1	Incubator	Php 2200	Php 2200
1	Box of latex gloves	Php 200	Php 200
2 tablets	Potassium Metabisulfite	Php 25	Php 50
2 grams	Diammonium Phosphate	Php 15	Php 30
1 pc	Airlock	Php 50	Php 50
		TOTAL PRICE	Php 8,394

Table 2: Apparatus/Equipment Used Per Trial

Equipment	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
Blender	✓	✓	✓	✓	✓	✓
Knife	✓	✓	✓	✓	✓	✓
Strainer	✓					
Chopping Board	✓	✓	✓	✓	✓	✓
Cheese Cloth			✓	✓	✓	✓
Aluminum Spoon	✓					
Glass Stirrer		✓	✓	✓	✓	✓
1L Beaker	✓	✓	✓	✓	✓	✓
1L Schott Bottle	✓	✓	✓	✓	✓	✓
250 mL Schott Bottle	✓					
Food Weighing Scale	✓	✓	✓	✓	✓	✓
pH Meter	✓	✓	✓		✓	✓
Incubator		✓				
Hydrometer			✓	✓	✓	
Refractometer			✓			✓
Airlock			✓	✓	✓	✓
6L PET Bottle	✓	✓	✓	✓	✓	✓
Funnel				✓	✓	✓

➢ *Procedure*

Before the researchers are able to conduct a comparative analysis of bioethanol sources available in the Philippines, the researchers will gatherdata on cassava and sugarcane on its ethanol content, sugar/starch percentage, and annual yield in the Philippines. Using Christoph Meinrenken's Life Cycle Assessment, the researchers will focus on the objectives of the study as a basis for the interpretation of data. The data to be interpreted are within the collected data and the environmental impact of the bioethanol of the ethanol extraction. Moreover, additional data will be provided by the researchers as they extract the ethanol content and sugar/starch percentage on pineapples (Ananas Comosus).

With the current mandated 20% ethanol blend and projected additional ethanol plants by the Department of Energy (DOE) up to year 2030, the researchers aim to introduce a new source of ethanol which will undergo an experimental process. The experiment will undergo five phases. These are the gathering of materials, preparation of materials, extraction process, content analysis, and ethanol yield calculation.

➢ *Gathering of Materials*

Before the experimentation process proceeds, the needed materials and chemicals are obtained first. With that, the pineapples to be used are gathered from the nearest supermarket where the experiment took place. The chemicals such as Saccharomyces cerevisiae (Yeast), Diammonium Phosphate (DAP), and Potassium Metabisulfite (KSM) alongside the airlock were bought from Dr. Bigol. Other chemicals such as Natrium Hydroxide (NaOH), Hydrochloric Acid (HCL), and laboratory materials such as beakers and Schott bottles are bought from an online shop platform. The graduated cylinder, volumetric flask, and glass stirrer are borrowed from the chemistry laboratory of the Philippine State College of Aeronautics - Villamor Campus. Other apparatus such as the pH meter and refractometer are also bought in an online shop. Additional materials are bought on the local markets only. These are the latex gloves, funnels, and droppers.

➢ *Preparation of Materials*

The researchers bought the pineapples in a supermarket in which they asked the vendor to weigh them with peels first. The vendor then peeled them and weighed them again. As the pineapples were already peeled, the researchers chopped them finely. The chopped pineapples will be put into a blender until it becomes a juice. This is done to prepare them for the fermentation process in which only the pure juice will be kept. Before all the apparatus were used, they were cleaned through a pasteurization process using distilled water. This is to ensure that all unnecessary bacteria will be eliminated. The container to be used, which is the PET bottle, was emptied and cleaned.

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V. FERMENTATION PROCESS

A. Filtration

After the materials to be used are prepared, alongside the pineapples, the fermentation process begins with filtration. In this segment, the blended number of pineapples was filtered using cheesecloth or "katsa" as an alternative. The researchers squeezed them portion by portion. In each portion squeezed with the help of cheesecloth, the juice is measured on the food scale. This procedure is repeated until the researchers gather the desired total volume of juice extracted from the pineapples. After weighing, they are directly poured into the PET bottle. The residue is set aside to be thrown away.

B. Dilution of Juice

After spending time on the filtration of extracted pineapple juice, the researchers added a liter of distilled water to dilute the juice. After pouring 1 liter of distilled water with the help of a funnel, the mixture was stirred in a calm manner using a glass stirrer. This is to follow the 1:1 ratio recommended by Prof. Mario B. Bigol if the amount of filtered juice is also 1 liter. After the juice had been diluted with a liter of distilled water, 1 gram of Diammonium Phosphate (DAP) was added to the mixture of extracted juice and distilled water for its additional nutrients. Diammonium phosphate (DAP) is an additional source of nutrients for nitrogen to be delivered to the yeast cells (BeerCo.com.au, 2023). Nitrogen is necessary for fermentation since it contains elements that convert sugars into ethanol. It is recommended that nitrogen is added at the beginning during the stationary phase to reduce the chances of stuck fermentations (Jean-Marie Sablayrolles, 2015).

C. Sugar Adjustment

With the added nutrients to the mixture, which was the DAP, sugar adjustment was done. In this process, the computation discussed by Prof. Mario B. Bigol followed. This is where the desired sugar percentage, which is 25%, was subtracted to the initial sugar rate of the extracted juice and distilled water mixture. The initial sugar rate was subtracted from 25% to get its difference. The difference is then multiplied with the volume of the mixture. The result is then the number of grams of sugar added to the mixture. With that being said, the appropriate grams of sugar were added. It was then stirred well with a glass stirrer to make sure that the sugar was dissolved. According to Prof. Bigol, the optimal sugar concentration for yeast growth and fermentation is between 20- 30% (w/v), with 25% being a commonly used value. This is because at higher sugar concentrations, the yeast cells experience osmotic stress and are unable to grow or ferment efficiently. On the other hand, at lower sugar concentrations, the yeast cells are unable to produce sufficient ethanol, resulting in lower yields. Hence, adjusting the sugar concentration to 25% in ethanol fermentation helps to maintain optimal conditions for yeast growth and fermentation, resulting in maximum ethanol production.

D. pH Adjustment

In the mixture, the desired pH level is 4 as recommended by the Africa Journal of Microbiology Research Volume 4. If the pH level of the pineapple is below 4, 5M (molar solution) of natrium hydroxide will be added. On the other hand, if the pH level is higher than 4, 1M (molar solution) of hydrochloric acid will be added. As the researchers aimed for a level 4 pH, they added a solution of 20 grams of Sodium Hydroxide (NaOH) with 100 mL of distilled water accordingly.

E. Chemical Pasteurization

As an alternative to the traditional pasteurization, chemical pasteurization was done. In this process, a tablet of potassium metabisulfite (KSM) was used. According to Professor Bigol, a tablet of KSM, is good for 3.8. The tablet weighed 0.3 grams. With that, the researchers computed how much KSM will only be used for the current mixture. A crushed gram of KSM was then computed to be mixed gently with the diluted pineapple juice. The container was then closed using its lid with the airlock attached to its top. The airlock was filled with cotton balls inside topped with paper and then sealed with a rubber band. The researchers set the container aside for 24 hours for the chemical pasteurization to take place. Chemical pasteurization is a non-thermal process used to disinfect the juice and protect it against harmful microorganisms. (Anne Marie Helmenstine, Ph.D. 2019) Potassium metabisulfite (KMS) releases SO2 which plays an important part in sterilizing and antioxidation. KMS is added before the yeast, to kill molds, bacteria and wild yeasts that might be present in the fruit. SO2 scavenges oxygen and prevents oxidation of the juice. (James Han, 2012).

F. Aerobic Fermentation

For the pineapple to undergo a 2-day aerobic fermentation the researchers prepared a computed amount of yeast (Saccharomyces Cerevisiae). If the computed amount of yeast is needed, 1g of it was rehydrated by mixing it with 10 ml of distilled water and set aside for 20 minutes. After the 20 minutes of yeast rehydration was done, it was mixed gently in the container of diluted pineapple juice. The lid of the container with the airlock was not replaced. The bottle was then shaken twice a day for 2 days and left at room temperature.

G. Anaerobic Fermentation

As the 2 days of anaerobic fermentation were completed, the researchers removed the cotton from the airlock and replaced it with distilled water. The juice and the container were recommended to be left for 7 to 14 days for the juice to undergo Anaerobic fermentation. In this procedure, shaking the bottle was not necessary anymore. A fermented broth can be expected after the completion of this process.

VI. DISTILLATION PROCESS

After the filtration, the ethanol yield will be measured by the chosen and available chemical engineer in the Department of Science and Technology at Taguig City using ethanol assay through the utilization of the dichromate colorimetric method. The glucose content, pH, and total soluble solids (TSS) will be then measured again for comparison purposes.

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➢ *Evaluation of the Product*

To evaluate the ethanol content of the pineapple, numerous trials were done until the necessary actions are polished. The procedures were also tweaked from time to time as to what is suitable in gathering data. The other trials were discussed with guidance by a professor from Department of Science and Technology - Industrial Technology Development Institute - Environment and Biotechnology Division (DOST – ITDI – EBD).

A. Trial #1

➢ *Gathering of Materials*

Each researcher prepared 2 pineapples bought from the nearest supermarket from their houses. The researchers prepared the following– a home kitchen knife, food processor, strainer, food scale, and disposable latex gloves.

Metallic spoon was used for stirring the pineapple product. NaOH was purchased from an online shop. An incubator was also bought in an online shop but only utilized on the second trial.

Fig 24: Trial 1 Gathering of Materials Incubator

Fig 25: Trial 1 Gathering of Materials: Sodium Hydroxide

Fig 26: Trial 1 Gathering of Materials: Schott Bottles

Fig 27: Trial 1 Gathering of Materials: Beaker and Strainer

Fig 28: Trial 1 Gathering of Materials: Rotten Pineapples

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➢ *Preparation of Materials*

Trial 1 was conducted in one of the researcher's condos in Merville, Paranaque City. The researchers stored the pineapples at room temperature for 14 days until rotten before it was chopped and extracted using a home kitchen blender. The extracted pineapple was stored in a Tupperware before it was transferred to a 1,000 mL beaker. Not all eight pineapples were used the 1,000 mL of pineapples were already reached. Leftover pineapples were disposed of properly.

Fig 29: Trial 1 Preparation of Materials: Blended

Fig 30: Trial 1 Preparation of Materials: Chopped Pineapples Pineapples

➢ *Fermentation Process*

- *Filtration*

Filtration was done using a kitchen strainer by the researchers. The pineapple residue was separated from the juice.

Fig 31: Trial 1 Fermentation Process: Filtration of Pineapples

Fig 32: Trial 1 Fermentation Process: Filtered Pineapples

- *Dilution of Juice*

No dilution process was done.

- *Sugar Adjustment*

No sugar adjustment was done.

- *pH Adjustment*

PH level reached 0 as the researchers tried to increase the pH level of the pineapple by adding NaOH powder directly. With that, it exceeded the4-pH standard level. To decrease the pH level, Hydrochloric Acid was added but it just resulted further in being hot creating a small amount of smoke.

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Fig 33: Trial 1 Fermentation Process: pH Adjustment

Fig 34: Trial 1 Fermentation Process: Adding of Sodium Hydroxide

Fig 35: Trial 1 Fermentation Process: Adding of Hydrochloric Acid

B. Trial #2

- *Gathering of Materials*

Pineapples A total of 5 pineapples were bought from the nearest supermarket of the researchers. Home kitchen knife, food processor, food scale, disposable latex gloves, pH meter are the apparatus used by the researchers. Stirring rod and 2 small type beakers were borrowed from the school laboratory. In this trial, the researchers bought an incubator to be used as a part of the fermentation process. Active and inactive chemicals used in the first trial to extract ethanol components from pineapples, such as yeast, sodium hydroxide, and hydrochloric acid, will be used again by the researchers.

Fig 36: Trial 2 Gathering of Materials

Fig 37: Trial 2 Gathering of Materials: Pineapples Laboratory Apparatus

- *Preparation of Materials*

Trial 2 was conducted inside the campus lab of Philippine State College of Aeronautics. The researchers stored the pineapples at room temperature for 14 days until rotten. Then, they were chopped, blended, and crushed in a blender. The extracted pineapple was stored in a Tupperware before it was transferred in a 1,000 mL beaker in PhilSCA's chemistry laboratory.

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Fig 38: Trial 2 Preparation of Materials: Blended Pineapples

Fig 39: Trial 2 Preparation of Materials: 1mL of Blended Pineapples

➢ *Fermentation Process*

- *Filtration*

  Filtration No filtration process was done.

- *Dilution of Juice*

  No dilution process was done.

- *Sugar Adjustment*

  No sugar adjustment was done.

- *pH Adjustment*

  The pH level only reached 1.8 pH and did not meet the 4pH standard level. The researchers tried to reach the level 4 of pH through continuously adding a mixture of 2 grams of NaOH with 10 mL of tap water. The solution was added until it reached a level of 2.5 pH level. As it reached the pH 3 Level, the researchers stopped adding NaOH and proceeded with adding yeast for the fermentation process. The pineapple was transferred to a 1,000 mL Schott bottle and was sealed. The bottle containing the fermented pineapple was incubated at 32.3° C for three consecutive days. The incubator also contained a 250 mL Schott bottle filled with distilled water to maintain moisture inside the incubator.

➢ *Computation*:

NaOH molecular mass: 39.997 g/mol NaOH (pH Adjustment Formula):

$$\frac{5\ mol}{L} = \frac{(xg\ NaOH)}{(39.997\ \frac{g}{mol})\ (1liter)}$$

$$x = ..g\ NaOH$$

- Needed Molarity: 5 mol Volume: 100 mL

$$\frac{100\ mL}{1000\ mL} = 0.1\ dm^3$$

- *Equation:*

  5 mol x 39.997 g/mol x 0.1 dm^3 = 20g NaOH for 100 mL, 5 mol

Fig 40: Trial 2 pH Adjustment: Measuring of pH Level

Fig 41: Trial 2 pH Adjustment: 20g of NaOH

Fig 42: Trial 2 pH Adjustment: 100 mL of Tap Water

Fig 43: Trial 2 pH Adjustment: Adding NaOH Mixture Incubation to Pineapple

Fig 44: Trial 3 pH Adjustment: pH Level

Fig 45: Trial 3 pH Adjustment: Measurement

C. Trial #3

➢ *Gathering of Materials*

The researchers obtained their container by asking for an empty 8-liter bottle in a local convenience store and 1 Liter of water was bought at the same store (7-11). A total of 20 pineapples were bought from a street vendor at the nearest supermarket in Brgy. 183 Villamor, Pasay City. The pineapples were peeled in preparation for their extraction. To reach the 2-liter needed amount of pineapple juice, 7 pineapples were used. Refined sugar was purchased from a local store. The needed chemicals such as Diammonium phosphate and Potassium metabisulfite were brought from Professor Mario B. Bigol. The researchers also bought yeast and an airlock from the same professor. The hydrometer and refractometer that the researchers used were borrowed from Prof. Mario B. Bigol. The pH meter used was bought from an online store. The researchers borrowed 1 stirring rod, 1 volumetric flask, and 1 graduated cylinder.

Fig 46: Trial 3 Gathering of Materials: Pineapples

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Fig 47: Trial 3 Gathering of Materials: Peeling of Pineapples

➢ *Preparation of Materials*

The researchers chopped the peeled pineapples into small pieces to easily blend them. After all the pineapples are chopped, they are put directly in the blender. This is done to prepare them for extraction in which only the pure juice will be kept. Before all the apparatus were used, they were cleaned through a pasteurization process using distilled water. This is to ensure that all unnecessary bacteria will be eliminated. The lid of the container was pierced to attach the airlock.

Fig 48: Trial 3 Preparation of Materials: Chopping of Pineapples

Fig 49: Trial 3 Preparation of Materials: Blending of Pineapples

➢ *Fermentation Process*

- *Filtration*

The blended pineapples were filtered using cheesecloth in order to separate the juice from the pulp. The pineapples were squeezed using the cheesecloth into a sanitized bowl until a total of 2 liters of pineapple juice was obtained. The juice was measured using a food scale. The pulp scraps were disposed. The researchers transferred the juice into the 8-liter container.

Fig 50: Trial 3 Filtration: Squeezing of Pineapple

Fig 51: Trial 3 Filtration: Weighing of Pineapples

Fig 52: Trial 3 Filtration: Disposing of Pineapple Juice Residues

- *Dilution of Juice*

The researchers added 1 liter of purified water into the 8-liter container with the pineapple juice and the solution was mixed with a stirring rod and the container was covered with a plastic sheet and rubber band tied around it. On the same day, the researchers went to SM Bicutan in order to buy the

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chemicals and for consultation about the process as well. The percentage sucrose of the pineapple was measured using the refractometer and the initial results from the brix reading showed that the diluted juice had a total of 11.6% brix. 2.1 grams of DAP was added for additional nutrients as recommended by Prof. Bigol.

Fig 53: Trial 3 Dilution of Juice: Purified Water

- *Sugar Adjustment*

Since the required percentage of sucrose is 25% Brix, the amount of table sugar needed was calculated. The sugar was measured using a food scale. The amount of sugar calculated was added into the diluted juice. The researchers stirred the sugar using the glass stirring rod until it dissolved. The researchers measured the percentage of sucrose using the hydrometer. The target result was 25% brix so the researchers kept calculating and adding sugar until it reached the desired 25% Brix.

- *Computation*:

Desired brix degree of sugar - initial brix degree of sugar = lacking brix degree of sugar

Volume of solution x lacking brix degree of sugar = needed amount of grams

- *Solution:*
  25% - 11.6% = 13.4%
  3000 mL x 0.134 = 402g of sugar
  (computation was repeated until the desired brix degree of sugar was reached)

Fig 54: Trial 3 Sugar Adjustment: Using Hydrometer

Fig 55: Trial 3 Sugar Adjustment: Weighing Sugar

Fig 56: Trial 3 Sugar Adjustment: Mixture Sugar

Fig 57: Trial 3 Sugar Adjustment: Adding Sugar to the PET Bottle

Fig 58: Trial 3 Sugar Adjustment: Sugar Percentage at 25%

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- *pH Adjustment*

The pH meter was calibrated in order to get accurate readings. The researchers measured the pH level of the pineapple. The measured pH level was 3.45. With that, the pH values of the juice did not meet the requirement of pH 4. NaOH was measured using the food scale and the amount of distilled water was measured using a graduated cylinder. The researchers added the NaOH solution. When the NaOH was incorporated, the pineapple juice was measured again to get a Ph level of 4.18.

- *Computation*:

NaOH molecular mass: 39.997 g/mol NaOH (pH Adjustment Formula):

$$\frac{5\ mol}{L} = \frac{(xg\ NaOH)}{(39.997\ \frac{g}{mol})(1liter)}$$

$$x = ..g\ NaOH$$

Needed Molarity: 5 mol Volume: 100 mL

$$\frac{100\ mL}{1000\ mL} = 0.1\ dm^3$$

- *Equation:*

5 mol x 39.997 g/mol x 0.1 dm^3 = 20g NaOH for 100 mL, 5 mol

Fig 59: Trial 3 pH Adjustment: Making NaOH Solution

Fig 60: Trial 3 pH Adjustment: Adding NaOH Solution to PET Bottle

Fig 61: Trial 3 pH Adjustment: pH level at 4.18

- *Chemical Pasteurization*

Once the desired pH level was achieved the researchers calculated the amount of KMS needed. The tablet was crushed and measured using the food scale. 0. 78g of the KMS was added into the juice to pasteurize it. The juice was stirred using the stirring rod in order for the KMS to be dissolved. The container was closed using the lid with the airlocked attached to it. The container was placed on the floor and was kept at room temperature. The researchers waited 24 hours in order to kill unnecessary microorganisms present in the juice.

Fig 62: Trial 3 Chemical Pasteurization: One Tablet of Potassium Metabisulfite

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Fig 63: Trial 3 Chemical Pasteurization: Crushed Potassium Metabisulfite

- *Aerobic Fermentation*

Fig 64: Trial 3 Aerobic Fermentation: 20 mL Purified Water

Fig 65: Trial 3 Aerobic Fermentation: 2g of Yeast Mixture

Fig 66: Trial 3 Aerobic Fermentation: Airlock with Tissue as Lid

In order for the pineapple to undergo aerobic fermentation the researchers added 2g of Yeast into the juice then stirred on a 20mL purified water as recommended by Prof. Bigol. The researchers added cotton to the airlock and the lid was closed. The bottle was shaken twice a day for 2 days and left at room temperature.

- *Anaerobic Fermentation*

The researchers removed the cotton from the airlock and replaced it with water. The juice and the container were left as is for 9 days in order for the juice to undergo Anaerobic fermentation. In this process, shaking the bottle twice a day was not applied anymore. This is to let the leftover residue drown and leave the juice on the upper part of the bottle to easily siphon after.

Fig 67: Trial 3 Anaerobic Fermentation: Airlock with Water and its Lid

Fig 68: Trial 3 Anerobic Fermentation: Airlock Attached on the Bottle

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Fig 69: Trial 3 Anerobic Fermentation: Day 1

- *Siphoning*

After 9 days, the fermented broth was siphoned using a tube bought from a local hardware store in Brgy. 183, Villamor, Pasay City in order to separate the juice from any residue left over. The percentage sucrose was tested using a hydrometer and resulted into 21% brix which was not the desired amount since a high level of sucrose means a low level of alcohol content. On the last day of fermentation, it can be observed how all the residue resided on the bottom part and the pineapple juice changed its color to a darker tone.

Fig 70: Trial 3 Siphoning: Fermented Pineapple

Fig 71: Trial 3 Siphoning: Tube Used for Siphoning

- *Distillation Process*

After siphoning the 3-liter fermented pineapple, only 2 liters were left to make sure all the residue was left out. As the rate of the sucrose level went down by 2% only. Despite that, the 2-liter fermented broth still underwent the distillation process handled by the DOST - ITDI – EBD headed by Ma'am Ursela G. Bigol's, PhD, RM, DPAM using the Heidolph Hei-Chill 250 rotary evaporator (RotaVap). The distillation process was conducted for three days. This is where the 2 liters were divided into two as to perform the distillation within 50 ° C and 69 ° C to not surpass the boiling point of ethanol, 78.37°C.

Fig 72: Trial 3 Distillation: Fermented Pineapple on 23% Sucrose Level

Fig 73: Trial 3 Distillation: Heidolph Hei-Chill 250 Rotary Evaporator (RotaVap)

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Fig 74: Trial 3 Distillation: 925mL of Ethanol Produced from 50°C Distillation

Fig 75: Trial 3 Distillation: 400mL of Ethanol Produced from 69° C Distillation

Fig 76: Trial 3 Distillation: Aqueous Solution Left from the Distillation

D. Trial #4

- *Gathering of Materials*

The researchers' fourth trial gathered their materials such as pineapples at the nearest supermarket of Brgy. 183 Villamor, Pasay City on a street vendor. In accordance with that, the pineapples were weighed first before the vendors peeled them. It weighed a total of 4.5kg. After the 4 pieces of pineapples were peeled, they were weighed again which resulted in 2.15 kg. The distilled water was bought on Metro Supermarket from the same Barangay. Old laboratory materials were utilized again. Additional materials were bought from a market nearby the researchers' house. The latex gloves were bought from Bulacan, where one of the researchers resides. Meanwhile, cheese cloth, dropper, and funnel were obtained from Fairview, Quezon City. The needed chemicals were still the ones bought from the first trials.

Fig 77: Trial 4 Gathering of Materials: 4.55kg Unpeeled Pineapples

Fig 78: Trial 4 Gathering of Materials: Peeling Pineapples

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Fig 79: Trial 4 Gathering of Materials: 2.15kg Peeled Pineapples

➢ *Preparation of Materials*

The researchers chopped the pineapples into small pieces to easily blend them. After all the pineapples are chopped, they are put directly in the blender. This is done to prepare them for extraction in which only the pure juice will be kept. Before all the apparatus were used, they were cleaned through a pasteurization process using distilled water. This is to ensure that all unnecessary bacteria will be eliminated. Using of latex gloves were also utilized to avoid contamination and sticky feeling.

Fig 80: Trial 4 Preparation of Materials: Cleaning Laboratory Apparatus with Distilled Water

Fig 81: Trial 4 Preparation of 100 Materials: Chopping Pineapples

Fig 82: Trial 4 Preparation of Materials: Blending Pineapples

➢ *Fermentation Process*

- *Filtration*

After the materials to be used are prepared, alongside with the pineapples, the extraction process begins with filtration. In this segment, the blended 4 pineapples were filtered using cheesecloth. The researchers squeezed them portion by portion. In each portion squeezed with the help of cheese cloth, the juice is measured on the food scale. This procedure is repeated until the researchers gather a total volume of 1.5313 liters of juice extracted from the pineapples. The residue is set aside to be thrown away.

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Fig 83: Trial 4 Filtration: Squeezing of Pineapples


Fig 84: Trial 4 Filtration: Weighing Pineapple Juice

Fig 85: Trial 4 Filtration: Sealed 1L Pineapple Juice

- *Dilution of Juice*

After spending time on the filtration of extracted pineapple juice, the researchers did not reach the 2-liter quota. This has led them to a decision to continue this on the following day to gather more pineapples needed. The accumulated juice poured into the 6-liter PET bottle was sealed with its cap.

- *Sugar Adjustment*

Unfortunately, on the next day of the supposed sugar adjustment, the bottle exploded like a wine cork that flies due to the high pressure inside. The bottle's cap created an impact on the researchers and made a loud noise. With that, it was decided to start another trial and consider it as a failure as observed. Big bubbles were seen on the bottle and were showing unstable particles. With that, it was decided to be disposed of and prepare for the next trial instead.

E. Trial #5

➢ *Gathering of Materials*

The researchers' fifth trial gathered their materials such as pineapples at the nearest supermarket of Brgy. 183 Villamor, Pasay City on a street vendor. This time, a total of 8 pineapples were bought. Concerning the past procedures, the pineapples were weighed first before the vendors peeled them. The first 5 pineapples were bought in the morning which weighed a total of 3.26kg. After the pineapples were peeled, they were weighed again which resulted in 2 kg. As the 5 pineapples only produced 1.7 liters of juice, additional 3 pineapples were bought in the afternoon. With that, the researchers succeeded in accumulating 2 liters of extracted pineapple juice. Old laboratory materials were utilized again but were rest assured cleaned with distilled water. Extra materials such as Latex gloves were utilized from the box bought on the last trial. The needed chemicals were still the ones bought from the first trials. Meanwhile, the PET bottle that will be used as a container is obtained from Metro Supermarket at Newport Pasay City in which a 6 - liter of Absolute distilled water was bought.


Fig 86: Trial 5 Gathering of Materials: Five Peeled Pineapples

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Fig 87: Trial 5 Gathering oF Materials: Additional 3.25kg of Unpeeled Pineapples

Fig 88: Trial 5 Gathering Materials: of Materials: Additional 1.56kg Peeled Pineapples

➢ *Preparation of Materials*

Applying the preparation done on the last trials, the researchers chopped the pineapples into small pieces to easily blend them. After all the pineapples are chopped, they are put directly in the blender. This is done to prepare them for extraction in which only the pure juice will be kept. Before all the apparatus were used, they were cleaned through a pasteurization process using distilled water. This is to ensure that all unnecessary bacteria will be eliminated.

Fig 89: Trial 5 Preparation of Materials: Chopped Pineapples

Fig 90: Trial 5 Preparation of Materials: Finely Chopped Pineapples

Fig 91: Trial 5 Preparation of Materials: Blended Pineapples

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➢ *Fermentation Process*

- *Filtration*

After the materials to be used are prepared, alongside the pineapples, the extraction process begins with filtration. In this segment, the blended 4 pineapples were filtered using cheesecloth. The researchers squeezed them portion by portion. In each portion squeezed with the help of cheesecloth, the juice is measured on the food scale. This procedure is repeated until the researchers gather a total volume of 1.5313 liters of juice extracted from the pineapples. The residue is set aside to be thrown away.

Fig 92: Trial 5 Filtration: Pouring Blended Pineapples on Cheesecloth

Fig 93: Trial 5 Filtration: Squeezing Cheese Cloth with Blended Pineapples

Fig 94: Trial 5 Filtration: Weighing Squeezed Pineapple Juice

Fig 95: Trial 5 Filtration: Pouring Squeezed Pineapple Juice into PET Bottle

- *Dilution of Juice*

After spending time on the filtration of extracted pineapple juice, the researchers did not reach the 2-liter quota. This has led them to a decision of continuing this on the following day to gather more pineapples needed. The accumulated juice poured on the 6-liter PET bottle was sealed with its own cap. To add nutrients, 2.1 grams of DAP was added.

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Fig 96: Trial 5 Dilution of Juice: 1000mL Distilled Water


Fig 97: Trial 5 Dilution of Juice: Attached Funnel

Fig 98: Trial 5 Dilution of Juice: 2.1 DAP

- *Sugar Adjustment*

With the added nutrients to the mixture, which was the DAP, sugar adjustment was done. The initial percentage of the sugar was 9% only. Following the computation discussed by Prof. Mario B. Bigol. This is where the desired sugar percentage, which is 25%, was subtracted to the initial sugar rate of the extracted juice and distilled water mixture. The initial sugar rate was 9%. With that, the difference of 16% was multiplied with the volume of the mixture. The result is then the number of grams of sugar added to the mixture. With that being said, 480 grams of sugar was added. It was then stirred well with a glass stirrer to make sure that the sugar was dissolved. After thoroughly mixing, the sugar rate went up by 16%. The same computation was done making the extracted pineapple solution go up by 20%. As the 25% sugar quota was not yet reached, another 200 grams was added based on the same computation.

- *Computation*:

Desired brix degree of sugar - initial brix degree of sugar = lacking brix degree of sugar

Volume of solution x lacking brix degree of sugar = needed amount of grams

- *Solution:*

25% - 9% = 16%

3000 mL x 0.16 = 480g of sugar

(computation was repeated until the desired brix degree of sugar was reached)


Fig 99: Trial 5 Sugar Adjustment: 9% Sucrose Level on Hydrometer

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Fig 100: Trial 5 Sugar Adjustment: Weighing Needed Sugar

Fig 101: Trial 5 Sugar Adjustment: 16% Sucrose Level on Hydrometer

Fig 102: Trial 5 Sugar Adjustment: 20% Sucrose Level on Hydrometer

- *pH Adjustment*

The initial pH of the mixture was 3.58. As the researchers aimed for a level 4 of pH, they added a solution of 20 grams Sodium Hydroxide (NAOH) with 100 mL distilled water. After pouring the whole solution, the mixture of extracted pineapple juice started changing color into a darker yellow. The bottle was also observed to be getting hot. With that, the researchers have found out that the amount of NAOH solution added was too much and the last trial's computation was not applicable anymore. The pH level was measured again and it turned out that it is already on a pH level of 10. The researchers tried to lower down the pH level by adding droplets of Hydrochloric Acid (HCl). After dropping a small amount, its pH level was measured again but was found out to be not absolutely effective. Rather than risking the use of a large amount of Hydrochloric Acid (HCl), the researchers have just decided to go on another trial.

- *Computation*:

NaOH molecular mass: 39.997 g/mol NaOH (pH Adjustment Formula):

$$\frac{5\ mol}{L} = \frac{(xg\ NaOH)}{(39.997\ \frac{g}{mol})(1 liter)}$$

$$x = ..g\ NaOH$$

Needed Molarity: 5 mol

Volume: 100 mL

$$\frac{100\ mL}{1000\ mL} = 0.1\ dm^3$$

➢ *Equation*:

5 mol x 39.997 g/mol x 0.1 $dm3$ = 20g NaOH for 100 mL, 5 mol

Fig 103: Trial 5 pH Adjustment: 3.58 pH Level on pH Meter

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Fig 104: Trial 5 pH Adjustment: 10.79 pH Level on pH Meter

Fig 105: Trial 5 pH Adjustment: Darker Color of Pineapple with 10.79 pH Level

F. Trial #6

➢ *Gathering of Materials*

In this trial, a total of 7 pineapples were bought. In relation to the past procedures, the pineapples were weighed first before the vendors peeled them. The 7 pineapples bought weighed a total of 5.02 kg. After the pieces of pineapples were peeled, they were weighed again which resulted in 2.73 kg. As observed from the past trials, the pineapples are getting smaller in size as months have passed from its season of abundance. The price was also getting higher despite the small size of pineapples. The laboratory materials and equipment gathered on the past trials were utilized once again. To gather the sugar/sucrose percentage in an easier manner, the researchers bought a refractometer from Angono, Rizal through an online marketplace. Extra materials such as Latex gloves were utilized from the box bought on the last trial. The needed chemicals were still the ones bought from the first trials.


Fig 106: Trial 6 Gathering of Materials: 5.02kg of Unpeeled Pineapples


Fig 107: Trial 6 Gathering of Materials: 2.73kg of Peeled Pineapples

➢ *Preparation of Materials*

Applying the preparation done on the last trials, the researchers chopped the pineapples into small pieces to easily blend them. After all the pineapples are chopped, they are put directly in the blender. This is done to prepare them for the fermentation process in which only the pure juice will be kept. Before all the apparatus were used, they were cleaned through a pasteurization process using distilled water. This is to ensure that all unnecessary bacteria will be eliminated. Meanwhile, the PET bottle used in this trial was from the last one and was cleaned with distilled water until the unnecessary smell wasremoved.

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Fig 108: Trial 6 Preparation of Materials: Chopping Pineapples


Fig 109: Trial 6 Preparation of Materials: Boiling Katsa" with Distilled Water

VII. FERMENTATION PROCESS

A. Filtration

After the materials to be used are prepared, alongside with the pineapples, the fermentation process begins with filtration. In this segment, the blended 8 pineapples were filtered using cheesecloth. The researchers squeezed them portion by portion. In each portion squeezed with the help of cheese cloth, the juice is measured on the food scale. With the weight of peeled pineapples bought, it was expected by the researchers that they would reach the needed 2 liters of pineapples. But as the researchers continued doing the same procedure of filtration, it only reached a total of 1 liter. One and a half pineapple was still not used yet even so filtrating them, it will not reach the 2 - liter quota. The researchers have decided to proceed with the 1:1 ratio instead. The ratio to be done was discussed with Prof. Bigol to avoid mistakes. The residue is set aside to be thrown away.


Fig 110: Trial 6 Filtration: Squeezing Pineapples


Fig 111: Trial 6 Filtration Weighing Squeezed Pineapples


Fig 112: Trial 6 Filtration: Pouring Pineapples in PET Bottle

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B. Dilution of Juice

After spending time on the filtration of extracted pineapple juice, the researchers added a liter of distilled water to dilute the juice. After pouring 1 liter of distilled water with the help of a funnel, the mixture was stirred in a calm manner using a glass stirrer. This is in accordance with the 1 liter of filtrated pineapple and 1 liter of distilled water ratio. As a new ratio is done, the researchers calculated again the amount of Diammonium Phosphate (DAP) appropriate for the mixture. With that, 0.5 gram of DAP was added to the mixture of filtered juice and distilled water for its additional nutrients as recommended by Prof. Bigol.

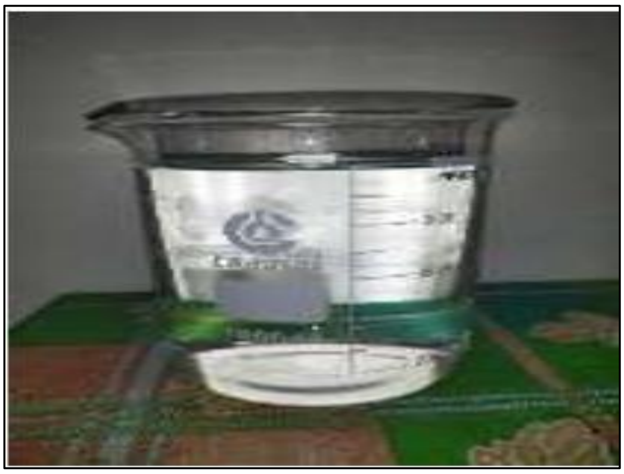

Fig 113: Trial 6 Dilution of Juice: 1000mL Distilled Water

Fig 114: Trial 6 Filtration: 0.5 Diammonium Phosphate

C. Sugar Adjustment

Having observed from the past trials that the sugar was not easily dissolved, the researchers alongside Dr. Bigol has decided to make the ratio of the mixture a 1:1 instead of 2:1. This is in accordance with the 1 liter of filtered pineapples only. The initial percentage of the sugar was 7% only. Followingthe computation discussed by Prof. Bigol. This is where the desired sugar/sucrose percentage, which is 25%, was subtracted to the initial sugar rate of the extracted juice and distilled water mixture. With that, the difference of 18% was multiplied with the volume of the mixture. The result is then the number of grams of sugar added to the mixture. With that being said, 360 grams of sugar was added. It was then stirred well with a glass stirrer to make sure that the sugar was dissolved. This time it was mixed with 1000 mL of the diluted pineapple juice with a portion of sugar first and was repeated until the sugar was dissolved. After thoroughly mixing, the sugar/sucrose rate went up by 18.25%. The same computation was done making the extracted pineapple solution go up by 22.4%. To reach the 25% sugar/sucrose quota, another 56 grams was added based on the same computation.

D. Computation:

Desired brix degree of sugar - initial brix degree of sugar = lacking brix degree of sugar

Volume of solution x lacking brix degree of sugar = needed amount of grams

➢ *Solution*:

25% - 7% = 18%

2000 mL x 0.18 = 360g of sugar

(computation was repeated until the desired brix degree of sugar was reached)

Fig 115: Trial 6 Sugar Adjustment: Drop of Diluted Pineapple on a Refractometer

Fig 116: Trial 6 Sugar Adjustment: Measuring the Sucrose Level Through Refractometer

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Fig 117: Trial 6 Sugar Adjustment: Weighing Needed Amount of Sugar

Fig 118: Trial 6 Sugar Adjustment: 1000mL of Diluted Pineapple on a Beaker

Fig 119: Trial 6 Sugar Adjustment: Adding Needed Amount of Sugar on 1000mL of Diluted Pineapple on a Beaker

Fig 120: Trial 6 Sugar Adjustment: Mixing the Additional Needed Amount of Sugar on 1000mL of Diluted Pineapple on a Beaker Using a Glass Stirrer

Fig 121: Trial 6 Sugar Adjustment: Measuring the Sucrose Level Through Refractometer

E. pH Adjustment

To measure the pH level, a pH meter was used which was calibrated first with a distilled water. A small amount of the mixture was poured on a bowl to measure the pH. With that, it was discovered that the pH of the mixture was already 3.61. As the researchers avoid committing the same mistakes, they did not raise it to level 4 pH. This is due to the high level of pH already. For this process, pH adjustment was not done as the level 4 of pH was recommended by the Africa Journal of Microbiology Research Volume 4. On the other hand, if the pH level is higher than 4, 1M (molar solution) of hydrochloric acid will be added.

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Fig 122: Trial 6 pH Adjustment: 3.61 pH Level on a pH Meter

F. Chemical Pasteurization

As an alternative to traditional pasteurization, chemical pasteurization was done. In this process, a tablet of potassium metabisulfite (KSM) was used.

According to Dr. Bigol, a tablet of KSM is good for 3.8 liters. The tablet weighed 0.78 grams. With that, the researchers computed how much KSM will only be used for the current mixture. A crushed 0.41g of KSM was then computed to be mixed gently to the diluted pineapple juice. The container was then closed using its lid with the airlock attached on its top. The airlock was filled with cotton balls inside topped with a paper and then sealed with a rubber band. The researchers set the container aside for 24 hours for the chemical pasteurization to take place.

Fig 123: Trial 6 Chemical Pasteurization: One Tablet Potassium Metabisulfite

Fig 124: Trial 6 Chemical Pasteurization: Crushed of Potassium Metabisulfite

- *Aerobic Fermentation*

For the pineapple to undergo a 2-day aerobic fermentation the researchers prepared a 1g of yeast (Saccharomyces Cerevisiae). Unlike the past trials with 2 grams of yeast, the computation differs now and so does the amount of chemicals used. The 1g of yeast was dehydrated by mixing it with a 10 ml distilled water and set aside for 20 minutes. After the 20 minutes of yeast dehydration was done, it was mixed gently in the container of diluted pineapple juice. The lid of the container with the airlock was not replaced. The bottle was then shaken twice a day for 2 days and left at room temperature.

Fig 125: Trial 6 Aerobic Fermentation: 1g of Yeast

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Fig 126: Trial 6 Aerobic Fermentation: 10mL Distilled Water

Fig 127: Trial 6 Aerobic Fermentation: Yeast Mixture with Distilled Water

Fig 128: Trial 6 Aerobic Fermentation: Pouring Yeast Mixture

Fig 129: Trial 6 Aerobic Fermentation: Securing with Airlock and Cotton

- *Anaerobic Fermentation*

The researchers removed the cotton from the airlock and replaced it with water. The juice and the container were left for 7 days in order for the juice to undergo Anaerobic fermentation.

Fig 130: Trial 6 Anaerobic Fermentation: Day 1 of Anaerobic Fermentation

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Fig 131: Trial 6 Anaerobic Fermentation: Secured with Airlock and its Lid

VIII. DESCRIPTIVE STATISTICS

Brief informational coefficients known as descriptive statistics are used to sum up a given data set, which may be a sample of a population or a representation of the entire population. The process of using statistical techniques to describe or summarize a set of data is known as descriptive analysis, also referred to as descriptive analytics or descriptive statistics.

Descriptive analysis, one of the main types of data analysis, is well-liked for its capacity to produce understandable insights from uninterpreted data.

In this study, the researchers will briefly explain how the three different crops differ from each other in terms of their harvest season, fermentation time, and distillation time. The appropriate time of producing certain ethanol will also be explained. With the help of descriptive statistics, the distilled data from 50° C and 69° C will be interpreted on its characteristics as a good complementary feedstock in utilizing bioethanol products.

The trials conducted by the researchers are explained with the insights observed from the results they have produced. As the data gathered resulted from different grounds of ethanol production, descriptive analysis was done as to whether it was more suitable.

IX. PRESENTATION OF THE FINDINGS

The preparation method of experimenting to produce ethanol emphasizes how tiny details can alter the result. Several trials are done to come up with the desired percentage of ethanol produced by a pineapple. The researchers found out how crucial the fermentation period was alongside with the yeast activation present in the diluted pineapple juice. A total of six trials were conducted but only two trials achieved a level of sucrose suitable to undergo the ethanol testing. With that, a comparative analysis is done to prove how pineapples can be a new ethanol substrate. This is to show how the available ethanol in the Philippines have the same components as the pineapples.

- *Descriptive Statistics*

A total of six trials have been conducted for the experimentation of the research study, where it progressed differently. The researchers finalized the process with the Department of Science and Technology - Industrial Technology Development Institute - Environment and Biotechnology Division (DOST – ITDIEBD) and Professor Mario B. Bigol. Each trial has corresponding phases met.

However, the trial that reached the distillation process were distilled in different degrees, 60° and 70° respectively.

On the first trial, pH level resulted in 0. No result of sugar level content was recorded as no sugar adjustment was done. With that, filtering of the residue and pineapple juice was done. Thus, no ample data was gathered.

On the second trial, fermentation process was reached with an initial 1.8 pH level which then led to 2.5 by adding NaOH solution. As no sugar adjustment was made, no sucrose data was gathered.

On the third trial, the researchers were able to discuss the experiment with DOST – ITDI – EBD that enabled them to enhance the procedures further. With that, this trial reached the distillation process handled by the DOST – ITDI – EBD. This trial was able to reach the pH level of 4 with an initial of 3.5 pH level with the help of NaOH solution. Sucrose level was also successfully obtained having an initial sucrose level of 11.6%. The distillation process was divided into 60° and 70° respectively.

On the fourth trial, filtering of the residue from the juice was the only progress made. This is because after leaving the extracted pineapple for a day with the PET Bottle lid on, it exploded right upon opening on the next day. With that, no ample data was also gathered.

On the fifth trial, the preparation for the fermentation period conducted. Thus, 3.58 pH level was documented as the initial pH level and 9% initial sucrose level. Upon pouring the 100 mL and 20g of NaOH, the pH level reached its peak and cannot be saved by drops of Hydrochloric Acid.

On the sixth and last trial, the fermentation process was also successful. An initial 7% of sucrose level was gathered with an initial pH level of 3.61. With that, only the sucrose level was adjusted. After 10 days, the fermented broth is now ready for distillation on DOST - ITDI – EBD and be tested further on Department of Energy.

➢ *Data Tables*

Table 3: Amount of Ethanol Produced from Different Centigrade

Pineapple Distillation at Different Degrees	Sugar Rate Upon Distillation	Ethanol Volume Produced
Distilled at 50°	23%	925 mL
Distilled at 69°	23%	400 mL

On the distillation process conducted by the DOST – ITDI – EBD, the fermented pineapple was distilled in different degrees centigrade in regards with the ethanol's boiling point. It is where they have produced different amount of ethanol from 1 liter each.

Table 4: Ethanol Production Timeline if Different Crops

Crop	Harvest Season	Fermentation Time	Distillation Time
Cassava	6 - 12 months / July - September	6 days	3 days
Sugarcane	8-10 months / October - December	5 days	3 days
Pineapple	16-18 months / April - July	10 - 14 days	3 days

As to compare the pineapple to cassava and sugarcane, the timeline of production was presented to determine how the ethanol from pineapple can be a substrate. This table presents how ethanol from pineapples can be produced from different months unlike the cassava and sugarcane.

X. SUMMARY OF FINDINGS

After conducting six trials, the researchers observed that conducting each trial enhanced the process of the past studies of pineapple as a bioethanol product. Upon observation, the researchers reported different progress from each trial. On the first trial, no data was gathered as the process of fermentation and extraction was done differently and no distillation process was done. Inthe second trial, the fermentation process was done by the researchers which gathered data of 2.5 pH level, initially 1.8 pH level, after NaOH solution was added. Unfortunately, data for sugar level was not gathered as no sugar adjustment was made. The researchers were able to discuss the experiment with DOST - ITDI - EBD on the third trial, allowing them to improve the procedures even further. This trial has now progressed to the distillation process, which is being handled by the DOST - ITDI - EBD. With the help of NaOH solution, this trial was able to achieve a pH level of 4 from a starting point of 3.5. Sucrose level was also obtained successfully, with an initial sucrose level of 11.6%. The distillation process was divided into two stages: 50°C and 69C°. This is where 925 mL of ethanol was produced within 50°C of distillation. Meanwhile, the 69°C distillation produced 400 mL of ethanol. The only progress made on the fourth trial was filtering the residue from the juice. This is due to the fact that after leaving the distilled pineapple for a day with the PET Bottle lid on, it exploded the next day when opened. Ample data was also gathered as a result of this. On the fifth trial, the preparation for the fermentation period was conducted. Data of 3.58 pH level was gathered as the initial pH level and 9% initial sucrose level. The pH level reached its peak after pouring the 100 mL and 20g of NaOH. Unfortunately, this trial cannot be continued even after adding drops of Hydrochloric Acid. The fermentation process was also successful on the sixth and final trial. An initial sucrose level of 7% was collected, along with an initial pH level of 3.61. Only the sucrose level was changed as a result of this. After 10 days, the fermented broth is ready for distillation on DOST-ITDI-EBD and recommended for further testing on DOE or other agency for its ethanol content.

The amount of ethanol volume produced must be met as it is required for testing in the Department of Energy (DOE). The researchers noticed that the ethanol produced from peeled pineapples produced more volume of ethanol than using peel wastes of pineapples. A total of 0.7181 liters of ethanol was produced from 9 kilograms of pineapple peels. Meanwhile, using the flesh of the pineapples gathered a total of 1.3 liters from 4 kilograms of pineapple meat. With the difference of their peak season, it was observed that within the month of July to September, cassava is the best crop to use in the production of ethanol. From October to December, ethanol production from sugarcane has its easiest gathering of crops. In April to July, best quantity and quality of pineapples can be expected.

Upon observation, the researchers concluded to consider the season harvest of the crops. Three factors differentiated the production of ethanol from the three different crops. The abundance of needed crops is determined by the timing of each crop's peak season. The typical harvest season for cassava is 6 to 12 months. This period lasts from July to September. Sugarcane, on the other hand, has a longer harvest season that lasts 8 to 10 months. This period lasts from October to December. However, gathering pineapples was easier because it has the longest harvest season of the crops mentioned. Pineapples can be harvested from 16 to 18 months, with the peak season being April to July. Sugarcane has the shortest fermentation time, requiring only 5 days of fermentation. According to that, cassava has the second shortest fermentation time, taking only 6 days. Pineapples, on the other hand, must be fermented for 10 to 14 days using aerobic and anaerobic fermentation. In terms of distillation time, all three crops can be distilled in three days.

In terms of the physical properties, the pineapple broth was yellow like pineapple juice. The odor was sweet like a pineapple even after undergoing chemical pasteurization and fermentation. The researchers discovered that the pineapple broth was not as viscous and liquid as water after the process. After undergoing the distillation process from DOST, the appearance of the broth, which is now ethanol, changed. The

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pineapple ethanol is as clear and as viscous as water. Its odor can be described as the smell of aged coconut red wine.

From the experiment that the researchers have conducted, out of 6 trials 5 of them have failed and 1 has succeeded from the ethanol yield production under distillation process. Although out of 6 trials, 4 failed and 2 succeeded from the fermentation process. The researchers assumed that the cause behind the failed trials during the preparation for fermentation process was due to the pH level and sugar adjustment. It is important to adjust the sugar level to 25% to activate the yeast.

In general, pineapple as a bioethanol substrate is feasible as it produces a large amount of ethanol volume as much as cassava and sugarcane bioethanol substrate that may be used in the Aviation industry.

XI. CONCLUSIONS

Given the results and the findings of data on this study, the researchers, therefore, concluded that the pineapple can be an ethanol additive. This is as the comparisons showed great similarity making the pineapple appear as a potential substrate. Also, the researchers concluded that the distilled pineapple requires further testing under the Department of Energy or any agencies conducting the necessary tests to provide its ethanol characteristics.

The pineapple is a good complementary feedstock in utilizingbioethanol in terms of ethanol production rate and sugar/sucrose composition. It can be shown in the data how the distilled fermented pineapple broth at 50° Centigrade produced 925 mL of ethanol. On the other hand, the distilled fermented pineapple broth at 69° Centigrade produced 400 mL of ethanol. Meanwhile, in terms of initial sugar rate, cassava produced the highest containing 25% sugar/sucrose level. Sugarcane came in second having a 12.5% of initial sugar/sucrose level. Lastly, pineapples had an initial sugar rate of 11.6%. The initial sugar/sucrose rate is critical in the fermentation process as it helps head start the yeast and produces cellular energy that turns into ethanol.

The abundance of crops in the Philippines has highlighted the difference in ethanol production with its timeline. In line with that, their yield of production per year shows how much crop can be harvested. According to Crops Statistics Philippines, in the year 2019, sugarcane produced the highest rate of crop with 20.72 million metric tons. Pineapples as the second to the highest having 2.74 million metric tons according to the Food and Agriculture Organization of the United Nations (FAO). Even globally, the Philippines ranked second in having the the highest rate of pineapple production. Lastly, the Department of Agriculture has stated that the production of cassava in the year 2019 was 2.6 million metric tons. Meanwhile, in terms of initial sugar rate, cassava produced the highest containing 25% sugar/sucrose level. Sugarcane came in second having a 12.5% of initial sugar/sucrose level. Lastly, pineapples had an initial sugar level of 11.6%.

Producing ethanol within the three different crops was differentiated in three factors. In gathering an amount of needed crop, the abundance depends on the timeline of each crop's peak season. For cassava, the usual harvest season lasts for 6 – 12 months. This is from July to September. Meanwhile, sugarcane has a longer harvest season ranging from 8 – 10 months. This is from October to December. However, the gathering of pineapples was easier as it has the longest harvest season time than the mentioned crops. Pineapples can be harvested from 16 – 18 months mostly from April to July as its peak season. On the fermentation time, sugarcane has the fastest one as it only requires 5 days of being fermented. In accordance to that, cassava was nextto the fastest fermentation time required as it only needed 6 days. On the other hand, pineapples need to be fermented for 10 to 14 days through aerobic and anaerobic fermentation. In terms of the distillation process, all three crops can be distilled in a span of 3 days.

RECOMMENDATIONS

In this research study, the researchers have recommendations that can help to improve and develop this project. Based on the findings and conclusions presented, the following recommendations are suggested.

- The researchers recommend a distillation process that will not go beyond the boiling rate of ethanol which is 78.37 °C to produce a large amount of ethanol.
- The researchers recommend persevering in the sugar adjustment of sugar level to 25% to successfully produce ethanol.
- The researchers recommend adding factors on the three crops of their characteristics for better comparisons.
- The researchers recommend producing ethanol in the harvest peak season of each crop for better quality.
- The researchers recommend using the aqueous solution left from the distillation process as a scent to the ethanol and other products such as soap.
- The researchers recommend allotting a minimum of two months to conduct the experimentation process.
- The researchers recommend testing the distilled pineapple with the Department of Energy or any other agencies conducting necessary testing to provide its different characteristics.
- The researchers recommend utilizing the pineapple juice and pulp since it is easier to blend compared to the tough skin.
- The researchers recommend to use fresh pineapples instead of rotten pineapples to avoid harmful microorganisms from developing.
- The researchers recommend integrating the NaOH at little amounts so that the solution does not become basic as well as to achieve the desired pH level.
- The researchers recommend chopping the pineapples into tiny bits in order for it to blend easier.
- Although a hydrometer is viable, to get a more accurate measurement of the percentage Sucrose the researchers recommended utilizing a refractometer.

- The researchers recommend to make use of other abundant crops in the Philippines with a higher production rate other than pineapples.
- The researchers recommend using sugarcane as a bioethanol source compared to the pineapple due to its higher ethanol percentage
- The researchers recommend to use bioethanol sourced from pineapples as an additive since sugarcane is not primarily used as a source for ethanol only.
- The researchers recommend disinfecting all equipment used with distilled water to further avoid the growth of bacteria.
- The researchers recommend to perform the extraction and fermentation process continuously.
- The researchers recommend to stir the refined sugar into the diluted juice at small amounts to make sure it gets dissolved completely.
- The researchers recommend to rehydrate the yeast with 35-37 degrees C of distilled water.
- The researchers recommend letting the pineapple juice ferment in a room-temperature area.

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