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# UTILIZATION OF PINEAPPLE WASTE AS A RAW MATERIAL FOR BIOETHANOL

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**Abstract**
Indonesia has large natural vegetable resources to be able to provide a promising and environmentally friendly alternative fuel to replace petroleum, namely bioethanol. Bioethanol is a biochemical liquid from the process of fermenting sugar from carbohydrate sources using the help of microorganisms. Bioethanol is produced from biomass containing sugar, starch and cellulose. One of the raw materials for bioethanol which is environmental waste is pineapple skin and pineapple hump. In this literature review, 15 articles were collected relating to the utilization of fruit waste as a raw material for bioethanol production and its effectiveness. The results from the literature review show that pineapple waste has suitable characteristics to be used as raw material for making bioethanol which is useful for environmentally friendly alternative fuels.

## INTRODUCTION

Indonesia as a country that has rich vegetable natural resources has a great opportunity to become a bioethanol producing country as a promising alternative material in the future. Bioethanol is produced from biomass containing sugar, starch and cellulose. Bioethanol is produced from biomass containing sugar, starch and cellulose (Arlianti, 2018). Bioethanol is a biochemical liquid from the process of fermenting sugar from carbohydrate sources using the help of microorganisms (Mandari et al., 2014). One of the raw materials that can be used as bioethanol is pineapple skin. Pineapple ( Ananas comosus L. ) is a tropical fruit commodity that can be found in Indonesia. Indonesia's pineapple production is quite large, based on the Fixed Figures (ATAP) in 2014 pineapple production reached 1.84 million tons(Arimba et al., 2019)

Consuming pineapples will provide quite a lot of waste in the form of skin, which is equal to 34.61% by weight, which still contains a carbohydrate content of around 10.54% and from research on making ethanol with pineapple peel extract, it is known that the glucose level of pineapple peel extract is 17% (Susanti et al., 2013). With the increasing production of pineapples, the waste generated will also increase. Utilization of pineapple skin waste is currently not optimal, usually pineapple skin waste is only used as animal feed. Judging from the amount of crude fiber, carbohydrates and glucose contained in pineapple skin which is quite high, it is possible for pineapple skin to be used as a raw material for the manufacture of bioethanol. One of the methods that can be used to produce bioethanol is the simultaneous saccharification and fermentation (SSF) process, also known as the simultaneous saccharification fermentation (SFS) process. The SSF process is a combination of hydrolysis using cellulase enzymes and the yeast Saccharomyces cerevisiae to ferment sugar into ethanol simultaneously. The performance of Saccharomyces cerevisiae in fermentation affects the conversion of sugar produced as the main product (Widyastuti et al., 2022). During the fermentation process microorganisms produce enzymes to hydrolyze the substrate into simple components (sugars) which then convert it into ethanol (Nursita et al., 2022).

This study aims to produce bioethanol from pineapple peel by Simultaneous Saccharification and Fermentation (SSF) with cellulase enzyme variations of 1%, 3%, 5%, 7%, and 10% v/v substrate and fermentation time is 2, 3, and 4 day.

## METHODS

The method used in this study uses a literature study by including an analysis of several articles. The document review activity is by discussing and evaluating similar previous research regarding the use of pineapple waste as a raw material for bioethanol. Several stages of the literature review method contain; 1) Selection of manuscripts, analyzed articles can be obtained by searching relevant literature using several online research platforms related to pineapple waste and Bioethanol (Researchgate, Google

Scholar and Publish or Perish). The articles used were from 2013 to 2023. The articles studied were journal articles in English and Indonesian. Related articles should focus on pineapple waste and bioethanol. Of the 15 articles giving a clear picture of pineapple waste and bioethanol. By monitoring titles and abstracts, journal articles are selected and checked by researchers to determine whether or not the article is suitable for the purpose of the research being carried out . A total of 12 articles met the criteria for inclusion in the final monitoring. 2) Analysis of the articles analyzed using qualitative content with a correlation between content and context (Nurwahyunani, 2021; Rusdiyana et al., 2021). The research articles were analyzed based on the discussion sub-categories according to the researcher's questions. The application of this category is to group research according to the variables studied. During the systematic monitoring process, several subcategories emerge and others can be refined to interpret the information that emerges (Paramita et al., 2019).

## RESULTS AND DISCUSSIONS

### The importance of developing renewable energy sources and the role of bioethanol in reducing dependence on fossil fuels

The need for energy for fuel oil (BBM) in many countries in the world in recent years has increased sharply because fuel is a basic human need. Most of the technology or even almost all means of transportation use petroleum as a source of energy. Crude oil is currently the main source of energy in industry, transportation and households. The high demand for oil is not matched by the quantity of production which over time has created an energy crisis (Kurniati et al., 2021). To anticipate the possibility of a fuel (BBM) crisis in the future, new renewable energy sources that are environmentally friendly have been developed.

**Table 1. Article data related to the importance of developing renewable energy sources and the role of bioethanol**

| The Importance of Developing Renewable Energy Sources and the Role of Bioethanol in Reducing Dependence on Fossil Fuels | | |
|---|---|---|
| **Pengarang** | **Judul** | **Jurnal** |
| Kurniati, Yuni, Iis Elfy Khasanah, & Kurniawati Firdaus, (2021) | Kajian pembuatan Bioetanol dari kulit nanas (*Ananas Comosus. L*) | Jurnal Kimia Teknik USU. |
| Siskayanti et al. (2021) | Pembuatan Bioetanol dari…… | Volume 8 Nomor 1, Januari-Juni 2023 |
| Rahmi.,et al. (2022) | Pemanfaatan Limbah Kulit Nanas menjadi Bioetanol……. | Chemical Engineering Journal Storage. |

New renewable energy (EBT) which is expected to replace petroleum is an alternative energy that can be recovered naturally and the process is sustainable, called biofuel . One example is bioethanol. Bioethanol is ethanol that is produced from (Kurniati et al., 2021) living things so that its presence can be renewed (Rahmi et al., 2022). ethanol or pure ethanol(Siskayanti et al., 2023).

**Characteristics of pineapple waste as raw material for bioethanol**

Pineapple peel is a lignocellulosic biomass which contains water, crude fiber, carbohydrates, protein, and reducing sugars. The presence of cellulose, hemicellulose and lignin components affects the amount of reducing sugar and bioethanol produced (Kurniati et al., 2021). Pineapple skin contains glucose and carbohydrates which is quite high, namely 13.65% and 17.53%. Carbohydrate content in pineapple skin consists of 21.98 ± 2.34% cellulose, 74.96 ± 2.55% hemicellulose and 2.68 ± 1.54% lignin (Nulhakim et al., 2019). Bioethanol can be produced from sugar-containing raw materials such as sugar cane, cassava, sago and pineapple (Syauqi & Inasari, 2020). The high fiber content in pineapple waste can be a potential source for the production of bioethanol fuel.

**Table 2 . Article data related to the characteristics of pineapple waste as a raw material for bioethanol**

| Characteristics of Pineapple Waste | | |
|---|---|---|
| **Author** | **Title** | **Journal** |
| Kurniati et al. (2021) | Kajian pembuatan Bioetanol dari kulit nanas (*Ananas Comosus. L*) | Jurnal Kimia Teknik USU. |
| Nulhakim et al. (2019) | Pembuatan Bioetanol dari Kulit Nanas oleh Saccharomyces Cerevisiae Terimobilisasi ……. | Seminar Nasional AVoER XI 2019 http://ejournal.ft.unsri.ac.id/index.php/avoer/article/view/410/324 |
| Syauqi & Inasari (2020) | Pemanfaatan Limbah Kulit Nanas | Buletin LOUPE Vol 16 No. 02, Desember 2020. |

High acidity where pineapple waste tends to have a low pH due to organic acid content, especially citric acid. This can affect the potential for soil and water pollution if not managed properly. Pineapple waste contains natural coloring compounds, such as bromelain and chlorophyll, which can be used in the food and cosmetic industries. However, the purification and utilization of these compounds in pineapple waste is still a challenge. Nutritional content in pineapple Despite having a high nutritional value,

pineapple waste has a relatively low nutritional content. This reduces the potential utilization of this waste as organic fertilizer. The potential for methane gas in pineapple waste can produce methane gas through an anaerobic combustion process. This gas has the potential as a source of renewable energy, but can also be a greenhouse gas that contributes to climate change.

**The process of making bioethanol through hydrolysis reactions**

In principle, the process of making bioethanol is carried out in several stages, including hydrolysis, fermentation and distillation. Hydrolysis is a chemical reaction between water and a substance that produces a new substance and the decomposition of a solution using water. Hydrolysis of cellulose can be done using an acid solution, alkaline solution, or enzymatically. In acid hydrolysis, the acid solution used is H2SO4 and HCl, while in alkaline hydrolysis, the solution usually used is NaOH . One of the enzymes that can be used in enzyme hydrolysis is the cellulose enzyme. (Kurniati et al., 2021).

**Table 1. Article data related to hydrolysis reactions in the manufacture of bioethanol**

| Hydrolysis Reaction in Making Bioethanol | | |
|---|---|---|
| **Author** | **Title** | **Journal** |
| Kurniati et al. (2021) | Kajian pembuatan Bioetanol dari kulit nanas (*Ananas Comosus. L*) | Jurnal Kimia Teknik USU. |
| Siskayanti et al. (2021) | Pembuatan Bioetanol dari Kulit… | Volume 8 Nomor 1, Januari-Juni 2023 |

Hydrolysis in the manufacture of bioethanol from pineapple peel is a step that aims to extract cellulose and hemicellulose into glucose and xylose which are reducing sugar products that can be converted into ethanol . Cellulose is a linear biopolymer consisting of anhydro D-glucose molecules connected or bonded to β-1,4 glycosidic hydrogen bonds for a linear and unbranched structure. Cellulose is the main component in lignocellulosic biomass which can be hydrolyzed to glucose (C 6 H 12 O 6 ) to be converted into biofuels. The source of cellulose is usually found in agricultural production waste. To produce sugar, cellulose goes through a hydrolysis process(Kurniati et al., 2021).

HCl is used as an acid catalyst because it is easily ionized, so the process of hydrolyzing pineapple peel powder to glucose will be faster. When H + ions from HCl form conjugated acids, the glycosidic bond is broken by adding a water molecule and breaking glucose and H + ions . This results in the concentration of an acid that can affect the acquisition of glucose(Siskayanti et al., 2023).

**Fermentation process in the manufacture of bioethanol**

Utilization of pineapple waste in bioethanol production involves several stages, namely: Stages pre-treatment Pineapple waste before it can be used in the fermentation process. This pre-treatment includes crushing, grinding, and dilution of the pineapple waste to separate the fermentable components. Continued fermentation after pre-treatment, pineapple waste can be used as a fermentation medium. Microorganisms such as Saccharomyces cerevisiae are used to convert the sugar contained in pineapple waste into ethanol. Then purification After the fermentation process, the ethanol produced needs to go through a purification stage to remove contaminants and produce pure bioethanol. Purification stages usually include distillation, drying, and filtering. Next, an analysis of the quality of the produced bioethanol needs to be analyzed for its quality, including the ethanol content, water content, pH, and purity. This analysis is important to ensure bioethanol meets the standards set.

**Table 2Article data related to the fermentation process in bioethanol production**

| **Process in Making Bioethanol** | | |
|---|---|---|
| **Author** | **Title** | **Journal** |
| Kurniati et al. (2021) | Kajian pembuatan Bioetanol dari kulit nanas (*Ananas Comosus. L*) | Jurnal Kimia Teknik USU. |
| Rohmah et al. (2021) | Pemanfaatan Kulit Nanas | CHEMTAG *journal of chemical engineering* |
| Fitria dan Lindasari, (2021) | Optimalisasi Perolehan Bioetanol dari Kulit Nanas (Ananas Cosmosus) dengan Penambahan Urea, Variasi Konsentrasi……. | Jurnal Online Institut Teknologi Nasional https://ejurnal.itenas.ac.id/index.php/lingkungan/article/view/3913/2305 |
| Syauqi, Inasari, (2020) | Pemanfaatan Limbah Kulit Nanas | Buletin LOUPE Vol 16 No. 02, Desember 2020. |
| Rahmi.,et al. (2022) | Pemanfaatan Limbah Kulit Nanas menjadi Bioetanol……. | Chemical Engineering Journal Storage. |
| Amelia, Fivi, Sulistiya Dewi, Minarti. (2021) | Produksi Bioetanol dari Bongol Nanas Madu dengan Variasi Konsentrasi Saccharomyces Cerevisiae dalam Pembuatan….. | Jurnal Ilmiah Teknosains, Vol. 7 No.2 https://journal.upgris.ac.id/index.php/JITEK/article/view/10000 |

Fermentation is a process of converting sugar into organic acids or alcohol. The microorganism used in the fermentation process is Saccharomyces cerevisiae (Kurniati et al., 2021). Saccharomyces cerevisiae can produce ethanol under anaerobic conditions and is able to take advantage of these conditions to grow and tolerate the ethanol produced (Rohmah et al., 2021). Saccharomyces cerevisiae under anaerobic conditions produces bioethanol (Fitria & Lindasari, 2021).

Fermentation is a decisive process in the production of bioethanol. The mechanism of the fermentation process consists of two stages, namely glycolysis and alcoholic fermentation (Kurniati et al., 2021). Fermentation is influenced by several factors including pH, yeast mass, and fermentation time. Based on Kurniati's research (2021) the optimum pH is in the range of pH 5 - pH 6. The highest ethanol content is obtained at a temperature of 30°C with a fermentation time of 168 hours, followed by a temperature of 35°C at a fermentation time of 48 hours. Both temperatures up to the end of the fermentation time still show an increase in ethanol levels, this is because the environmental conditions of the fermentation are suitable for the development of microbes as yeast which assist the fermentation process in the production of bioethanol.

Syauqi and Inasari's research (2020) showed that the pH of bioethanol with the highest value was at P1, with the addition of 75 grams of yeast. This is presumably because the yeast is added a little so that the microbes are not able to break down carbohydrates into sugar, alcohol and lactic acid. Meanwhile, at P2 and P3, the resulting pH decreases, presumably because the more yeast added, the more carbohydrates will be broken down into sugar, alcohol, lactic acid and other compounds so that the higher the amount of acid, the lower the pH of bioethanol.

The use of yeast mass and fermentation time also affect the concentration of ethanol produced (Kurniati et al., 2021). Increasing the mass of the yeast will increase the concentration of the resulting bioethanol. However, the greater the volume of yeast used, the lower the bioethanol concentration. Several studies have shown that the optimal mass of Saccharomyces cerevisiae is 1.5% - 2%. The addition of yeast increases the concentration of ethanol by increasing the activity of Saccharomyces cerevisiae in converting glucose into ethanol. The addition of this yeast lowers the concentration of the ethanol produced, because the amount of nutrients in the solution is not as much as the yeast at a higher concentration so that most of the yeast dies and the ethanol produced decreases (Kurniati et al., 2021).

Based on research by Syauqi and Inasari (2020) the yield of bioethanol in P1 is by adding 75 grams of yeast by 3.18%, in P2 is by adding 100 grams of yeast by 2.75%, and in P3 is by adding 125 grams of yeast by 1, 82%. This is presumably because in P1 the nutrients obtained are more than those in P2 and P3 due to the amount of yeast added, the nutrients obtained are decreasing, this causes the yield produced to also decrease. The yield of bioethanol produced was highest with the addition of 75 grams of yeast, namely 3.18%,

the pH test was close to SNI, namely with the addition of 75 grams of yeast, namely 4.10, the alcohol content test with the addition of 100 grams of yeast, namely 49.00% (Syauqi & Inasari, 2020).

In addition to yeast concentration, the length of time of fermentation also affects the concentration of the ethanol produced. Fermentation time is the time needed by Saccharomyces cerevisiae to convert or ferment glucose into bioethanol. The longer the fermentation time, the higher the level of bioethanol produced. However, if it takes too long the nutrients in the substrate will run out so that Saccharomyces cerevisiae cannot produce alcohol (Fitria & Lindasari, 2021).

Fermentation time is also related to the growth of the yeast Saccharomyces cerevisiae and can be illustrated by a growth curve showing each growth stage. There are 4 phases of growth, namely the adaptation phase, the fast growth phase, the stationary phase and the death phase. The adaptation period is represented by a curve from 0 to slightly increasing. During this stage, the yeast Saccharomyces cerevisiae undergoes a period of adaptation and does not grow. The period of rapid growth is described by a curve that begins to show strong growth. At this stage, the yeast Saccharomyces cerevisiae grows very quickly. During this stage, large-scale breakdown of sugars occurs to meet the growing demands of the yeast Saccharomyces cerevisiae .

The stationary phase is represented by a horizontal curve indicating that the number of surviving Saccharomyces cerevisiae is proportional to the number that died. The dead stage is shown by reducing the curve. During this period, more and more Saccharomyces cerevisiae die, until eventually all Saccharomyces cerevisiae die (Fitria & Lindasari, 2021).

Fermentation time will show the optimum time and optimal bioethanol yield. The longer the time required for the fermentation process, the higher the bioethanol content produced. However, fermentation has its own optimum time, so that after reaching the optimum time the concentration of ethanol produced will decrease, this is because the microbes are going to the death phase. Optimum time at 48 hours – 96 hours(Kurniati et al., 2021).

Based on the research of Rahmi et al (2022) fermentation with the fastest time, namely 3 days contains 25.314% ethanol content, 6 days fermentation contains 27.739% ethanol content, 9 days fermentation contains 38.492% ethanol content and 12 days longest fermentation contains ethanol content of 32.778%.

The ethanol content increases with the fermentation time. The increase in ethanol content that was seen at 9 days was due to Saccharomyces cerevisiae which was in yeast in its fermentation process still entering the log phase. In this phase, the microbes divide rapidly and constantly following a logarithmic curve. Whereas at 12 days the concentration of ethanol tends to decrease and does not show a range of increase like the initial fermentation day. When compared to the growth phase of microorganisms, this condition is due to the fermentation process starting to enter a slow growth phase (Rahmi et al., 2022).

Based on research by Amelia et al (2021) regarding the production of bioethanol from pineapple humps with varying concentrations of Saccharomyces cerevisiae, the highest average alcohol results were obtained in treatment A (Saccharomyces cerevisiae concentration of 1.5 grams and 100 ml honey pineapple hump liquid) obtained an average alcohol content = 1.883 % (A = 1.883). High or low bioethanol production can be seen based on the amount of sugar consumption and sugar growth during fermentation(Amelia et al., 2021)

Based on research (Rohmah et al., 2021)shows that at a glucose level of 24.12%, bioethanol is obtained with a level of 41.62%. This shows that the increasing glucose levels, the resulting bioethanol levels will also increase, because the glucose levels in the substrate fermented by the bacteria Saccharomyces cerevisiae are increasing.

**Distillation process in the manufacture of bioethanol**

The distillation process is carried out to separate the ethanol from the water. Distillation was carried out within 2 hours and at 105°C. Observations were made on the ethanol content of the fermented product for 24 hours to 120 hours (Susanti et al., 2013). During distillation, a vapor phase is formed as soon as the solution is heated. The vapor and liquid are allowed to come into contact with each other so that for sufficient time all the components present in the solution are gradually distributed to form the distillate. In distillates, many contain components with a higher pure vapor pressure or lower boiling point. Meanwhile, components with low pure vapor pressure or high boiling points are mostly present in the residue. (Susanti et al., 2013). In the first distillation the ethanol content is often lower than 95%, when in fact if this happens the distillation must be repeated until the ethanol content reaches 95%.(Wahyuni et al., 2016).

**Table 3. Article data related to the distillation process in the manufacture of bioethanol Process in Making Bioethanol**

| Author | Title | Journal |
|---|---|---|
| Susanti et al. (2013) | Making Bioethanol from Pineapple Skin Through Hydrolysis with Acid | EQUILIBRUM Vol. 12. No. 1. Pages: 11 – 16 https://jurnal.uns.ac.id/ekuilibrium/article/view/49635 |
| Wahyuni, (2016) | Utilization of Saccharomyces cerevisiae and Pineapple Waste from Beringharjo Market, Yogyakarta for Bioethanol Production | Sanitation, Journal of Environmental Health, Vol.7, No.4, May 2016, Pages 151 – 159 http://e-journal.poltekkesjogja.ac.id/index.php/Sanitas/article/download/725/492 |

| | | |
|---|---|---|
| Arimba et al. (2019) | Purification of Bioethanol from Pineapple Skin Waste Using a Reflux Column Model Simple Distillation Equipment | Zarah Journal, Vol. 7 No. 1 (2019) https://ojs.umrah.ac.id/index.php/zarah/article/view/1173/680 |

There are many types of distillation equipment used, one of which is a simple distillation model with a spiral distillation pipe model ( *feed stock system* ). The advantage, apart from being cheaper and easier to manufacture, is that during the cooling process the hot steam and cooling water will meet directly in the opposite direction ( *counter flow* ). This causes the ethanol vapor to condense faster and flow back into liquid(Arimba et al., 2019).

**Use of Bioethanol in All Fields**

Bioethanol is a type of renewable fuel produced through the fermentation process of biomass, such as agricultural waste and food waste. One of the potential sources for bioethanol production is pineapple waste. Pineapple waste contains organic matter which can be converted into bioethanol through a fermentation process. The use of bioethanol from pineapple waste has several advantages, including as a renewable energy source, reducing dependence on fossil fuels, and reducing negative impacts on the environment.

**Table 4. Article data related to the use of bioethanol in all fields**

| Use of Bioethanol in All Fields | | |
|---|---|---|
| **Author** | **Title** | **Journal** |
| Wahyuni, (2016) | Pemanfaatan Saccharomyces Cerevisiae dan Limbah Buah Nanas Pasar Beringharjo Yogyakarta untuk Pembuatan Bioetanol | Sanitasi, Jurnal Kesehatan Lingkungan, Vol.7, No.4, Mei 2016, Hal 151 – 159 http://e-journal.poltekkesjogja.ac.id/index.php/Sanitasi/article/download/725/492 |

In the industrial world, ethanol is generally used as raw material for alcohol derivatives, mixtures for alcoholic beverages such as sake or gin, as well as raw materials for pharmaceuticals and cosmetics. Bioethanol can also be used as an alternative fuel to replace gasoline, and as fuel in laboratories as a substitute for methylated spirits. Bioethanol production from pineapple fruit waste can be used as an industry(Wahyuni et al., 2016).

## CONCLUSION

Based on the discussion listed above, it can be concluded that pineapple waste can be used as a raw material for making bioethanol which can be used in various fields. In the manufacture of bioethanol is carried out through three stages, namely hydrolysis, fermentation and distillation. Hydrolysis of cellulose can be done using an acid solution, alkaline solution, or enzymatically. while the fermentation process through the stages of glycolysis and alcoholic fermentation using the microorganism Saccharomyces cerevisiae . The distillation process is carried out to separate the ethanol from the water.

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