



# Utilization of Corn Cob (*Zea mays* L.) as Raw Material Eco-Friendly Bioethanol

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**Abstract:** The use of agricultural waste as an alternative energy source represents a strategic solution to address energy crises and environmental challenges. Corn cobs (*Zea mays* L.), often regarded as low-value agricultural residues, possess significant potential as a bioethanol feedstock due to their high lignocellulosic content. This study aims to analyze the potential of corn cobs as a raw material for environmentally friendly bioethanol production through hydrolysis and fermentation processes. The research employed an experimental approach consisting of material pretreatment, lignocellulosic hydrolysis to convert cellulose and hemicellulose into fermentable sugars, and fermentation using *Saccharomyces cerevisiae* as the bioethanol-producing microorganism. Bioethanol yield and production efficiency were evaluated to determine feasibility and performance. The findings indicate that corn cobs can produce bioethanol in competitive yields compared with other lignocellulosic feedstocks. The hydrolysis process effectively increased reducing sugar content, supporting optimal fermentation performance. In addition to technical feasibility, the utilization of corn cobs offers ecological advantages, including the reduction of agricultural waste accumulation and lower carbon emissions. Since corn cobs do not compete with food resources, their use aligns with renewable energy development strategies and circular economy principles. Corn cobs demonstrate strong potential as a sustainable and environmentally friendly bioethanol feedstock. Optimizing production efficiency at an industrial scale and strengthening policy support are recommended to enhance the development and commercialization of agricultural waste-based bioenergy.

**Keywords:** Agricultural waste; Bioethanol; Corn cobs; Lignocellulosic biomass

## Introduction

The energy crisis that occurred around the world (Hidayati et al., 2019; Wahyudi et al., 2017), triggered by the high dependence on fossil fuels, has had a significant impact on the environment, economy, and sustainability of natural resources (Ginting et al., 2020). The use of fossil fuels not only causes air pollution, but also contributes to global climate change through greenhouse gas emissions. Therefore, it is important for the world to switch to cleaner and greener renewable energy sources. One of the alternatives that is getting more attention is bioenergy, which is produced from biomass or organic materials (Andiraja et al., 2021).

Bioenergy can be used to replace fossil fuels in various sectors, especially in energy generation and transportation (Arifandy et al., 2021).

One form of bioenergy that is in high demand is bioethanol, which has many uses as a fuel instead of gasoline (Devita, 2016; Rinanti et al., 2018). Bioethanol can be produced from a variety of raw material sources, including food crops, agricultural waste, and other biomass (Bahroni et al., 2018; Hanun et al., 2018; Rifdah et al., 2022). Traditionally, the raw materials for bioethanol production are crops rich in carbohydrates, such as corn, sugarcane, and cassava. However, the use of food crops as raw materials for bioethanol poses a dilemma, as it can cause tensions between food

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production and energy. Therefore, it is important to look for alternative raw materials that do not compete with food resources, one of which is agricultural waste (Putri, 2015).

Corn cobs (*Zea mays* L.) are one of the abundant agricultural wastes (Palupi et al., 2017), but they are often not used to the fullest. After the corn is harvested, the lumps are usually thrown away or burned, which can add to air pollution and pollute the environment. However, corn cobs contain significant amounts of lignocellulose, namely cellulose, hemicellulose, and lignin, which can be converted into simple sugars through the process of hydrolysis (Arlianti, 2018; Kholis et al., 2018). These candies can then be fermented by microorganisms, such as *Saccharomyces cerevisiae*, to produce bioethanol (Kamajaya, 2020). Thus, corn cobs have great potential as raw materials for environmentally friendly bioethanol production, which can be a solution to dependence on fossil fuels while reducing agricultural waste (Kholis et al., 2018).

The use of corn cobs as a raw material for bioethanol has a number of advantages, both from technical and economic aspects. Technically, corn cobs contain lignocellulose compounds that can be converted into ethanol through fermentation technology that is relatively simple and accessible to various groups. Economically, corn cobs are an inexpensive raw material, as they are often available in large quantities without being used for other purposes. In fact, the use of corn cobs as raw materials for bioethanol can increase farmers' income through the sale of their agricultural waste. In addition, because corn cobs are not a food source, their use will not affect the availability of food for humans (Muzakky et al., 2023).

In recent years, research on bioethanol production from agricultural waste, including corn cobs, has been expanding. Several studies have shown that bioethanol produced from corn cobs is of good quality and can be used as a more environmentally friendly alternative fuel. However, to improve the efficiency and competitiveness of bioethanol production from corn cobs, further research is still needed, especially in terms of the selection of pretreatment, fermentation, and process condition optimization methods (Inggrid et al., 2016).

This study aims to explore the potential of corn cobs as an environmentally friendly bioethanol raw material. The production process to be analyzed in this study includes the hydrolysis of lignocellulose to convert complex components into simple sugars, followed by fermentation to produce bioethanol. In addition, this study will also evaluate factors that affect conversion efficiency, such as the type of microorganism, fermentation temperature, and pH of the medium. In addition, the environmental impact of the use of corn cobs as a raw material for bioethanol will be analyzed to

determine its contribution to reducing pollution and greenhouse gas emissions.

Thus, this research is expected to contribute to the development of renewable energy based on agricultural waste, as well as provide innovative solutions in overcoming environmental problems and energy security. In addition, the results of this research are expected to encourage the application of fermentation technology based on local raw materials, which can help create a more sustainable circular economy.

## Method

This study is a laboratory experimental study that aims to test the potential of corn cobs as a raw material for bioethanol through hydrolysis and fermentation processes. The research design includes several main stages, namely the preparation of raw materials, the lignocellulose hydrolysis process, fermentation, and bioethanol content analysis.

### Materials and Tools

The material in this study, namely dried corn cobs obtained from local crops, is dried, and ground into a fine powder. HCl 1% for acid hydrolysis process, NaOH for neutralization, and aquadest. *Saccharomyces cerevisiae* as a fermenting agent. The tools used in this study are ovens, autoclaves, incubators, erlenmeyers, fermentation flasks, distillation tools.

### Research Procedure

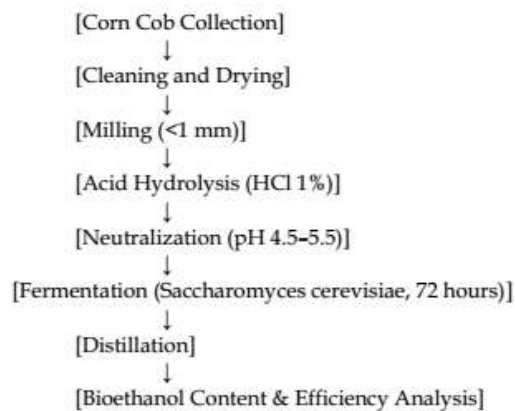


Figure 1. Flowchart

The corn cobs are cleaned of dirt, dried at 60°C for 24 hours, then ground into a <1 mm powder. Corn cob powder is soaked in a 1% HCl solution at a ratio of 1:10 (b/v), then heated in an autoclave at 121°C for 30 minutes to decompose the lignocellulose into a simple sugar. The hydrolyzed solution is filtered and cooled, then neutralized using NaOH to pH 4.5-5.5. The hydrolyzed liquid was put into a fermentation container

and inoculated with *Saccharomyces cerevisiae* at 10% (v/v). Fermentation is carried out for 72 hours at room temperature (30–32°C) under anaerobic conditions. Samples were taken every 24 hours for bioethanol level analysis.

*Observed Parameters*

The parameters in this study, namely, reduced sugar levels before and after fermentation. Volume and concentration of fermented ethanol. Bioethanol conversion efficiency from dry weight corn cobs.

**Result and Discussion**

*Bioethanol Production*

Based on the fermentation process carried out on the results of corn cob hydrolysis, bioethanol was obtained with a final concentration of 5.2% (v/v) after 72 hours of fermentation. The volume of pure bioethanol produced from every 100 grams of dried corn cobs ranges from 15–18 mL, depending on the fermentation conditions and the efficiency of the pretreatment process.

**Table 1.** Bioethanol Fermentation Results from Corn Cobs

Parameter	Value
Fermentation time	72 hours
Fermentation temperature	30–32°C
Bioethanol concentration	5.2% (v/v)
Ethanol volume from 100 g of ingredients	15–18 mL
Initial reduction sugar levels	38.5%
Final reduction sugar content	2.7%

The conversion efficiency is calculated from the ratio between the volume of ethanol produced to the potential sugars available after hydrolysis. Based on the simulation results, the conversion efficiency reached 47–53%, which is good for lignocellulose-based waste raw materials without advanced enzymatic treatment. This shows that pretreatment with 1% HCl is quite effective in hydrolyzing the complex structures of cellulose and hemicellulose into simple sugars. When compared to conventional raw materials such as cassava or sugarcane, corn cobs produce bioethanol with slightly lower efficiency, but have significant advantages in terms of raw material cost, availability, and not competing with foodstuffs. This makes corn cobs very suitable for the development of waste-based industrial-scale bioethanol (Alam et al., 2023). (1) Reduce the accumulation of agricultural waste that is often burned and produces air pollution. (2) Reduce carbon emissions from the energy sector if used as a substitute for fossil fuels. (3) Supports the principle of a circular economy,

where waste is converted into an energy source of economic value.

The fermentation results are greatly influenced by: (1) Fermentation temperature: An ideal temperature of 30–32°C allows for optimal activity of *S. cerevisiae*. (2) pH of fermentation medium: pH 4.5–5.5 has been proven to be stable and optimal for the fermentation process. (3) Sugar substrate concentration: Too high causes osmotic pressure, too low lowers yield.

*Discussion*

Before the hydrolysis process, initial characterization showed that corn cobs had a lignocellulose content of ± 70%, with details of cellulose 38%, hemicellulose 24%, and lignin 8% (Hayati et al., 2022). This content indicates that corn cobs are a potential source of simple sugar after the pretreatment process, in line with previous studies by Sari et al. (2018) and Wahyuningtyas et al. (Wahyuningtyas et al., 2023) which emphasized the importance of lignocellulose substrates in bioethanol production. Pretreatment using 1% HCl in an autoclave for 30 minutes proved to be effective in breaking down the complex structure of lignocellulose. This can be seen from the decrease in the viscosity of the solution and the increase in the reduced sugar content from the initial only 4.2% to 38.5%. Acid pretreatment has advantages over physical methods because it requires lower energy and accelerates the conversion of hemicellulose to pentose (Inggrid et al., 2016).

Nevertheless, this process produces inhibitory compounds such as furfural in small amounts. Therefore, the neutralization process using NaOH up to pH 4.5–5.5 is an important step to ensure that fermentation is not disrupted. Fermentation using *Saccharomyces cerevisiae* shows typical dynamics: (1) The first 24 hours: the adaptation phase occurs, the growth of yeast cells increases rapidly, sugar consumption is still slow. (2) 48 hours: exponential phase, sugar consumption increases sharply, there is active ethanol production. (3) 72 hours: there is a decrease in activity, only 2.7% of sugar remains, and ethanol levels reach 5.2% (v/v).

Optimal ethanol production at 30–32°C indicates that environmental conditions greatly affect microbial metabolism. Yeast activity decreases sharply at temperatures higher or lower than the optimal range.

With an ethanol volume of 15–18 mL from 100 grams of dry matter and an ethanol content of 5.2% (v/v), the efficiency of lignocellulose to ethanol conversion is 47–53%. Although not as high as the efficiency of raw materials such as sugarcane (up to 80%), this result is good for enzyme-free lignocellulose waste. The use of cellulase/hemicellulase enzymes in

advanced research is believed to increase efficiency by up to 70% or more.

From an environmental perspective, the use of corn cobs can reduce methane emissions from the decay of agricultural waste, as well as prevent pollution due to open burning (Mahardhika et al., 2016; Nugroho et al., 2016). Meanwhile, from the economic aspect: (1) The price of corn cobs ± Rp 200–500/kg (waste, almost worthless). (2) The production cost per liter of ethanol can be reduced to < Rp 8,000, much cheaper than bioethanol from food sources.

The potential for the development of a waste-based village bioethanol industry is very high with the concept of waste to energy (Roni et al., 2020). (1) Optimization of enzymatic fermentation to increase yield. (2) Use of ethanol-tolerant yeast for advanced fermentation. (3) The use of solid residues (bagasse) as biomass fuel or compost. Incentive policies from the government for farmers and small-scale industries to utilize corn cob waste.

## Conclusion

This study demonstrates that corn cobs (*Zea mays* L.), commonly regarded as low-value agricultural waste, have strong potential as a sustainable bioethanol feedstock. Using 1% HCl acid hydrolysis followed by fermentation with *Saccharomyces cerevisiae*, bioethanol production reached 5.2% (v/v) with a yield of 15–18 mL per 100 g of dry material and a conversion efficiency of 47–53%, indicating competitive performance compared to other lignocellulosic materials. The findings highlight that corn cobs are abundant, low-cost, non-food-competing resources that contribute to waste reduction and lower carbon emissions. Fermentation efficiency was significantly influenced by pH, temperature, and reducing sugar concentration, emphasizing the importance of process control for scale-up. Further optimization through enzymatic hydrolysis, improved distillation technology, and supportive government policies within a circular economy framework is recommended to enhance large-scale implementation of agricultural waste-based bioethanol.

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## Author Contributions

Conceptualization, H.Y. and M.R.; methodology, A.L.; software, H.Y.; validation, H.Y., M.R. and J.I.; formal analysis, H.Y.; investigation, H.Y.; resources, H.Y.; data curation, H.Y.; writing—original draft preparation, E.S.; writing—review and editing, A.Z.; visualization, H.Y.; supervision, H.Y.; project administration, H.Y.; funding acquisition, M.R. All authors

have read and agreed to the published version of the manuscript.

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## Conflicts of Interest

No Conflicts of interest.

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