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BIOETHANOL: THE GREEN FUEL ALTERNATIVE

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Abstract

Bioethanol, derived from biomass, is now emerging as a sustainable alternative to traditional fuels like fossil fuels. This green fuel is produced through the fermentation of sugars, starch, and lignocellulosic materials. This will contribute to the reduction in greenhouse emissions and promote energy security. Further enhancement in bioethanol production is aided by technological advancements and the usage of much more efficient microorganisms. This article explores the bioethanol production process, from substrate pretreatment to ethanol recovery and the byproduct processing.

Overview

Bioethanol is a renewable source of energy which is gaining widespread attention as an alternative to fossil fuels. It's a promising green fuel alternative as we seek cleaner and sustainable energy sources. Primarily produced through fermentation of biomass, bioethanol offers a solution for reducing greenhouse emissions and promoting energy security. Usage of this biomass for biofuel production promotes a circular economy by utilizing waste materials and the technological advancements as well as the usage of efficient microorganisms make bioethanol to be a key player in the global renewable energy solution.

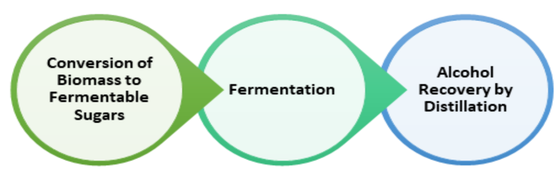
Steps in Ethanol Production

Bioethanol production mainly consists of 3 steps:

1.Conversion of biomass to fermentable sugars: Biomass like sugar, starch, or lignocellulosic materials are broken down into simpler sugars.

2.Fermentation: Conversion of biomass such as sugar, starch, or lignocellulosic materials into ethanol through a biochemical process.

3. Alcohol recovery by distillation: Ethanol from the fermentation mixture is separated and concentrated through distillation.



Steps in Bioethanol Production

Substates Used for Bioethanol Production

Sugars like sugarcane, sugar beet, molasses and whey are used. Starchy materials like cereals and corn, tubers like cassava and potato are also used. Agricultural residues like lignocellulosic materials such as wood chips and grasses can also be utilized.

Pretreatment of Substrates

The sole purpose of pretreatment is to make sugars more available for fermentation.

For sugary substrates, water extraction or dilution is used.

In the case of starchy substrates, it is a multi-step process that involves soaking, grinding, cooking, and enzymatic liquefaction to break down the starch to glucose.

Soaking and germination aid in activating the enzymes and making starch more available and it is followed by drying and grinding to a fine powder to increase the surface area. It is then cooked and subjected to liquefaction.

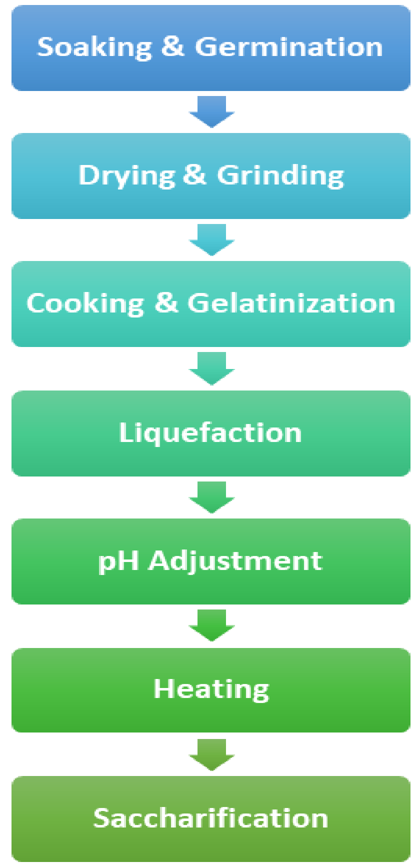
The enzyme α-amylase breaks down starch into small molecules like dextrins. pH of about 5.9 to 6.2 is preferred and can be adjusted using ammonia and sulfuric acid.

Further heating is done followed by saccharification where an enzyme like glucoamylase converts the starchy substrates into simple sugars like glucose.

Lignocellulosic materials like agricultural residues are broken down to cellulose via steam explosion and enzymatic hydrolysis.

Steam explosion is the process where the wood chips are heated (2600 C) under high pressure (600 psi) and rapidly depressurized making them break down into simple structures.

It is then followed by enzymatic hydrolysis by cellulase enzymes using microorganisms like *Trichoderma reesei* which converts cellulose to glucose.



Pretreatment of Starchy Substrates

Desirable characteristics of Microorganisms

- High growth & fermentation rates
- Tolerance to physical & Chemical stress
- High ethanol yield
- Osmo-tolerance
- Ethanol & Glucose tolerance (Tolerate high concentrations of glucose & ethanol)
- High-temperature tolerance
- Low pH tolerance

Microorganisms used in fermentation process

Traditionally yeasts are used for fermentation. Species like Saccharomyces cerevisiae, S. uvarum, and Kluyveromyces fragilis are the most exploited ones. Since they have a narrow substrate range and low ethanol tolerance, bacteria can be used as an alternative. The potential candidate for this is Zymomonas mobilis, which can produce ethanol more efficiently. Zymomonas mobilis produces ethanol 3-4 times faster than traditional yeast. It doesn't require oxygen for growth and only needs a minimal medium. It is highly osmotolerant and optimal growth is observed in the temperature range from 38°C to 40°C. The main drawbacks are, that it has low salt tolerance and can only ferment glucose, fructose, and sucrose.

Process of fermentation

The fermentation process involves the substrate preparation with suitable sugars. Suitable pretreatment procedures are done and it is followed by adding 4% v/v microorganisms as inoculum. This should be maintained at a pH of 4-6 depending on the substrate and product and also a temperature range between 21-30°C. The process of fermentation begins under aerobic conditions and later shifts to anaerobic fermentation (batch or continuous culture) which lasts about 2-3 days and then ethanol recovery and byproduct processing is done. Typically, 45-50% ethanol is the final yield from 100 g of carbohydrates.

Ethanol Recovery

Ethanol is recovered through a series of steps viz. Cell separation, Initial distillation, Rectification, and Azeotropic distillation. During cell separation, the cellular debris is removed from the fermentation broth via centrifugation. The broth then undergoes initial distillation yielding about 12-15% ethanol. This distillate is rectified and 95.6% ethanol concentration is achieved. However this is the problematic part in ethanol recovery since 95.6% ethanol forms an azeotropic mixture with water. The hydroxyl groups bond strongly between water and ethanol. This mixture boils at 78.2°C while pure ethanol has a boiling point of 78.5°C which makes the separation difficult. It can't be easily separated by simple distillation hence azeotropic distillation using benzene is done. Benzene is added to the azeotropic mixture which aids in increasing the boiling point of ethanol and lowers the boiling point of water and benzene. This process helps in separating the absolute alcohol by collecting it from the bottom while water and benzene are distilled with the gradual increase in temperature. Zeolites are used for further dehydration leaving pure ethanol behind.

By-products of Bioethanol Production

The by-products which are produced by this process should also be taken care of for the completion of the bioethanol production. They should be processed in such a way that there are no harmful effects to the environment as well as making use of those by-products for making other useful products. The solid residues from ethanol production are turned into Distillers' Dry Grains with Solubles (DDGS) which is used as animal feed. CO_2 from the fermentation process is collected and compressed and used in carbonated drinks, the production of dry ice, and other applications. By-product management should be done for higher economic gain

Simultaneous Saccharification & Fermentation (SSF)

Another aspect concerning bioethanol production is the Simultaneous Saccharification and Fermentation (SSF) which is an advanced technique where booth the enzymatic hydrolysis and fermentation occur in a single vessel. Examples include; Aspergillus glucoamylase and yeast cells are added to partially hydrolyzed starch for fermentation. In the case of cellulosic substrates bacteria like Trichoderma reesei along with yeast are added for the production of bioethanol from cellulose.

Direct Conversion of Cellulosic Biomass

Bioethanol can be produced directly from cellulosic biomass. C.thermohydrosulfuricum, C. thermosaccharolyticum, and Clostridium thermocellum are classes of thermophilic bacteria which are having the property of producing cellulase. They have the ability to convert cellulose directly to ethanol. However these bacteria have lower ethanol tolerance compared to the traditional microbes like yeasts and Zymomonas mobilis. The process is somewhat efficient since clostridial fermentation produces organic acids as by-products.

Conclusion

Bioethanol is a promising alternative fuel and prompts the shift towards sustainable energy sources. Its production process also helps in the utilization of waste materials but also contributes to reducing environmental impact. Bioethanol has the potential to play a significant role in addressing the global energy crisis while supporting a circular economy.

References

1. Busic, A., Marđetko, N., Kundas, S., Morzak, G., Belskaya, H., Šantek, M. I., Komes, D., Novak, S., & Šantek, B. (2018). Bioethanol Production from Renewable Raw Materials and Its Separation and Purification: A Review. Food Technology and Biotechnology, 56(3), 289-311. https://doi.org/10.17113/ftb.56.03.18.5546
2. Sarkar, N., Ghosh, S. K., Bannerjee, S., & Aikat, K. (2011). Bioethanol production from agricultural wastes: An overview. Renewable Energy, 37(1), 19-27. https://doi.org/10.1016/j.renene.2011.06.045
3. Zabed, H., Sahu, J., Suely, A., Boyce, A., & Faruq, G. (2017). Bioethanol production from renewable sources: Current perspectives and technological progress. Renewable and Sustainable Energy Reviews, 71, 475-501. https://doi.org/10.1016/j.rser.2016.12.076