Review Paper

Generation of Bioethanol Using Organic Waste: A Sustainable Approach to Renewable Energy

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Abstract

Bioethanol is an appealing biofuel due to its potential to enhance energy security and promote environmental sustainability when compared to fossil fuels. A wide range of biomass resources has been explored for bioethanol production, which can generally be classified into three categories: sugars, starch, and lingo cellulosic biomass. However, the conversion of biomass into ethanol can vary significantly based on the nature of the feedstock, primarily due to differences in their biochemical composition. As a result, only a limited number of feedstocks have been commercially exploited. In recent years, the conversion process of biomass has advanced substantially, although many of these innovations have not yet been fully implemented in commercial-scale facilities. The key steps in the conversion process—especially the fermentation of sugars, a common step across all types of biomasses—are heavily influenced by the microorganisms used. These microorganisms play a crucial role in determining the efficiency and yield of bioethanol production. The growing demand for renewable energy has led to the exploration of bioethanol as a potential alternative to fossil fuels. One of the promising sources for bioethanol production is organic waste, which offers an opportunity for both waste management and energy generation. This paper reviews the production of bioethanol from various organic waste materials, including agricultural residues, food waste, and municipal solid waste. The process of bioethanol production through fermentation, utilizing lingo cellulosic biomass, and the role of microorganisms are discussed. The paper also addresses the environmental, economic, and social impacts of using organic waste as a feedstock for bioethanol, emphasizing the potential for sustainable, low-carbon energy production.

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INTRODUCTION

In a rising era of modernization and industrialization, the whole world relies on various energy sources like coal, oil, petrol, diesel, etc. However, the use of these energy sources has negatively impacted the environment as the excessive use of these energy sources resulted in a rise in the concentration of greenhouse gases leading to air pollution. Concurrently, the rise of population has deteriorated the fossil fuel reserves at faster rates. Thus, energy security and environmental safety are critical issues today, driving the need for alternative, eco-friendly energy sources [1-3]. Fossil fuel reserves are expected to be depleted within the next 40–50 years due to the rapid consumption of these non-renewable resources. Furthermore, burning fossil fuels contributes to greenhouse gas emissions and global warming, leading to climate change, rising sea levels, biodiversity loss, and urban pollution. In this regard, the production of biofuel from renewable sources like corn, grass, algae, and sugarcane is an attractive approach. Also, they will help to improve the world economy because their source of production can vary ranging from algae to organic waste. Bioethanol is a major source of energy as its production rises to 130 billion liters annually. Also, when produced from organic waste, bioethanol is non-toxic, uses renewable sources, and the emissions resulting from biofuel are less harmful. Moreover, the remains resulting from the combustion of bioethanol are less toxic [1,3].

Bioethanol, a promising alternative, can be produced from renewable carbohydrate-rich sources. Countries like the USA, Brazil, China, Canada, and several EU states have committed to bioethanol programs to reduce fossil fuel dependency, with the USA and Brazil leading the way. In response to growing demand, global bioethanol production has increased significantly, with the USA alone producing more than half of the world's ethanol by 2015. From 175 million gallons in 1980, U.S. ethanol production surged to 14,810 million gallons in 2015 [1-8]. Bioethanol, a typical alcohol derived from biomass, is considered a promising alternative renewable energy source that can reduce environmental degradation. Organic waste, including agricultural, industrial, and domestic waste, has emerged as an attractive feedstock for bioethanol production due to its availability, low cost, and environmental benefits. The availability of feedstock for the production of organic waste-generated bioethanol fluctuates from one season to another. The sugar-containing organic materials, starch-enriched raw materials, and linguistic biomasses are important sources for the production of organic waste-based bioethanol [1-6]. The present review focuses on bioethanol contents, raw materials used for production, synthetic approaches, and its applications. In the present review, we will focus on first- and second-generation modes of bioethanol production.

1. Bioethanol

Bioethanol is an eco-friendly oxygenated fuel, containing 34.7% oxygen, while gasoline lacks oxygen. This higher oxygen content leads to approximately 15% more efficient combustion in ethanol compared to gasoline, resulting in lower emissions of particulates and nitrogen oxides. Additionally, the amount of sulfur in ethanol is negligible, and blending it with gasoline helps reduce sulfur content and the emission of sulfur oxides, which are carcinogenic and contribute to acid rain. Bioethanol also serves as a safer alternative to methyl tertiary butyl ether (MTBE), commonly used to enhance gasoline's octane rating and ensure cleaner combustion by reducing carbon monoxide (CO) and carbon dioxide (CO_2) emissions. MTBE has been found to contaminate groundwater, posing serious health risks. In response, the U.S. Energy Policy Act of 2000 issued an Advance Notice of Proposed Rulemaking (ANPR) under the Toxic Substance Control Act (TSCA) to limit MTBE's use in gasoline [1-4].

2. First-generation and second-generation bioethanol

In the "first-generation" technology, bioethanol is produced by converting sugars directly from crops like sugarcane or sugar beets and indirectly through starch from corn, wheat, potatoes, or cassava through fermentation followed by distillation. The commercial production of bioethanol can be done using vegetable oils, sugar, starch, liquid manure, sugarcane, wheat, seaweeds, algae, and switch grass which are first-generation sources for the production of bioethanol. The long-term viability of this conventional process is in question because it will require a significantly increased amount of cultivable land and a significant hike in food prices that will ultimately lead to food insecurity. Therefore, it is essential to have alternative organic sources for the production of bioethanol [9-11]. Second-generation bioethanol produced from biomass is the most efficient and eco-friendly mode of production as it is carbon neutral. The production of bioethanol using various kinds of plant biomass is commonly referred to as "lignocellulosic materials". These are some of the most abundant materials on the planet that can serve as potential sources for bioethanol production. These materials contain a large number of sugars which can undergo various pre-treatments to result in bioethanol. Among various sources, rice straw is a potential feedstock as it contains cellulose, hemicellulose, and lignins, which have a high amount of sugar leading to consider it as a major second-generation biofuel. Thus, the preferred use of rice straw for bioethanol production leads to improved quality and low environmental pollution [12-16].

3. Feedstock and modes of production for bioethanol production using second-generation biofuels

In comparison to first-generation biofuels for the production of bioethanol, the use of second-generation biofuels is in huge demand. These biofuels help to lower the pressure on biodiversity by utilizing large amounts of biomass that goes unnoticed despite its abundance. In this regard, the use of second-generation biofuels has attracted researchers all over the world. Production of bioethanol using second-generation biofuels involves the use of solids, liquids, or gases that can be used for a variety of applications. These can involve the use of corn straw, wheat straw, grass, sugarcane baggase, etc. These biomasses contain cellulose, hemicellulose, and lignin with the amount of bioethanol production greatly affected by the chemical composition of each feedstock. The process for the formation of bioethanol from linguistic biomass involves a number of steps starting from pretreatment [18,19]. The first step involves breaking lignin followed by solubilizing and increasing hemicellulose and cellulose accessibility. The pretreatment allows more accessibility of biomass towards hydrolysis and fermentation which allows minimal loss in biomass maximising bioethanol yield. In the second step, hydrolysis is carried out which can take place with dilute acids or concentrated acid. This can also be accrued out using enzymatic hydrolysis of cellulases and xylanases, thus increasing overall production. The hydrolysis is followed by fermentation (batch fermentation, fed-batch fermentation, continuous) which is carried out with the help of bacteria, yeasts, and fungi. At the end of the process, a distillation of bioethanol is carried out which gives bioethanol as a product [18-20].

CONCLUSION

Bioethanol production from organic waste is a promising solution for addressing the global energy crisis, environmental pollution, and waste management challenges. With advancements in pre-treatment technologies and microbial fermentation processes, bioethanol can be produced efficiently from a wide range of organic waste materials. Sustainable bioethanol production will require integrated strategies, including waste management, technological innovation, and supportive policies to maximize its potential as a clean, renewable energy source. In conclusion, the social and policy implications of bioethanol production from organic waste are far-reaching. It has the potential to promote sustainable waste management, foster rural development, and create energy security. With the right policies and regulations in place, bioethanol can serve as a key component in transitioning to a more sustainable, low-carbon economy while addressing pressing social and environmental challenges.

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