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Review Article

Bioethanol: A Challenge to the Dominance of Fossil Fuels

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ABSTRACT

The rising concerns about ever-increasing demands of fossil fuels have raised questions on their environmental suitability and consumption rate. This futuristic paucity focuses on the need to shift towards renewable, cleaner, and economical fuels to meet endless energy demands. In this regard, bioethanol has emerged as an alternative source to fossil fuels. In the current review, we will explore how the bioethanol production has revolutionized the energy sector and its social and economic challenges and benefits associated. By looking into these aspects, bioethanol production can be directed towards more sustainable ways of producing these renewable energy sources.

KEYWORDS: Greenhouse Gases, Energy Sector, Bioethanol Production, Carbon Dioxide

INTRODUCTION

In spite of the huge environmental impact and limited availability of fossil fuels, the global energy market still relies on fossil fuels raising concerns over its depletion. This leads to significant energy challenges as the economy and lifestyle of present human beings rely on the use of fossil fuels like oil, coal, and natural gas. Fossil fuels are the primary source of energy and the transport sector is mainly responsible for its consumption. In the case of the transportation sector, greenhouse gases are produced by the combustion of fossil fuels (*e.g.*, gasoline and diesel) which account for more than 70% of global carbon monoxide (CO) emissions and 19% of global carbon dioxide (CO_2) emissions. Concurrently, the demand for fossil fuels has increased substantially over the past few decades [1-5]. Depending on the production and consumption rates, the presently known reserves of fossil fuels will not appreciably run out for at least 100 years or more, but the demand for oil consumption is expected to exceed production from known and anticipated oil reserves ten or twenty years from now which will lead to an increase in crude oil price thus affecting the global economy directly. The gradual exhaustion of traditional fossil fuels, combined with increasing energy consumption and greenhouse gas emissions, has spurred the search for alternative, renewable, sustainable, efficient, and cost-effective energy sources with lower emissions. This has intensified research in the field of renewable and environment-friendly energy sources that can reduce the burden of environmental pollution on Earth [1-8]. In this context, biofuels have emerged as an alternative fuel as they are renewable and clean fuels, and reduce dependence on fossil fuels. Biofuels are the direct substitute for fossil fuels and thus can reduce the reliance of India on oil imports. Biofuels like hydrogen, syngas, and natural gas are likely to become four crucial sustainable fuel sources in the foreseeable future. Biofuels, in particular, hold promise for numerous benefits in terms of energy security, economics, and the environment [1-10].

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Biofuels include liquid forms like ethanol, biodiesel, and pyrolysis oils, as well as gas forms. (biogas) and solid (fuelwood, charcoal, and wood pellets) fuels predominantly produced from biomass. The various types of biofuels, their methods of production, sources of biofuels, and their effects on the environment are listed in Table 1 below. Biofuels, primarily used for transportation, are easily sourced from biomass, help to maintain the CO_2 cycle, offer great potential for eco-friendly applications, and help combat climate change. These can be produced from agricultural waste or other organic materials, enhancing sustainability and economic independence to rural India through biomass production. Among the different biofuels, bioethanol has been considered in the world as the indispensable alternative renewable fuel with the largest potential to replace fossil-derived fuels, responsible for a significant fraction of greenhouse gas emissions [1-8]. Ethanol (C_2H_5OH), is a liquid that is flammable and has advantages like antiseptic properties, solvent, psychoactive agent, and widely used as a fuel in various industries. It can be derived from renewable agricultural sources (corn, sugar, molasses), is less toxic, and the byproducts of its oxidation are less harmful. This makes it an attractive fuel compared to traditional fossil fuels. The term bioethanol originates from its production using biomass sources like sugar crops, corn or starch-based crops. Bioethanol is a clean fuel with negligible greenhouse gas emissions, provides an energy haven, and can be made available without worrying about its depletion from Earth. It is an economic and scalable solution to deal with fossil fuel scarcity as its production can be done using diverse feedstock (biomass). However, the energy sector is still dominated by fossil fuels due to certain limitations posed by production methods, costs, and technological aspects [1-13]. This current review focuses on challenges faced by bioethanol in the energy sector and future perspectives.

Bioethanol vs. fossil fuels: A comparative analysis

The combustion of fossil fuels and their use for energy production is the primary source of emission of greenhouse gases (GHGs) and hence poses negative effects on Earth. In comparison to this, biofuels exclusively bioethanol have emerged as green fuel to combat climate change and deal with emissions of GHGs. Concurrently, fossil fuels aggravate economic instability and political tensions due to the limited availability and uneven distribution of fossil fuels. To deal with these issues, biofuels have emerged as renewable sources of energy production which are environment friendly. Production of bioethanol using different feedstock like lignocellulosic biomass has resulted in economic and sustainable ways. In addition to this, the use of unused biomass helps to reduce the burden of waste on Earth and generate energy via economic modes. The aggressive use of fossil fuels in the transportation sector raised concerns about carbon footprints in the environment. However, bioethanol production and use in the transportation sector reduce carbon footprints and hence contribute towards global climate targets. Beyond these benefits, their production offers diversification, and hence feedstock can be tailored based on geographical conditions. Thus, bioethanol supports as a translational source of energy for sustainable development [14,15].

Bioethanol Production and Its Role in the Energy Mix

Bioethanol is known as renewable fuel which is green as it does not emit greenhouse gases when used for energy production. It is known to reduce the emission of harmful gases by 71% when replacing gasoline in the energy sector. Bioethanol is well used and tested in the energy sector in progressive countries like Europe and the United States and hence is a safe fuel. However, due to its high production cost and complicated production methods, the production of bioethanol and its use is thus limited. Concurrently, due to the oil crisis, the production of bioethanol was still carried out and its production using microbial fermentation is an alternative approach to meet the global fuel demands. The production of bioethanol is quite a lengthy process consisting of several steps (i) choice of feedstock: the choice of feedstock in bioethanol production plays a major role as contents of cellulose, hemicellulose, and other materials decide the quality and yield of bioethanol, (ii) second essential step for production of bioethanol is pretreatment, which involves the breaking of feedstock into fermentable components. This can be carried out using various physical and chemical methods making the fermentation process easier and faster, (iii) The third crucial step is hydrolysis and followed by (iv) fermentation using efficient and cost-effective enzymes, (v) distillation is then carried out to obtain final bioethanol product.

Bioethanol production is generally carried out using corn, starch, or sugar-rich materials. However, the first-generation feedstock for bioethanol production competes with food crops and requires a large amount of land for cultivation and thus is of limited use. However, lignocellulose biomass (wheat straw, corn stover, switch grass) is in the limelight for the production of bioethanol. This feedstock often termed second-generation fuels helps to reduce the burden of waste on Earth along with the conversion of trash to treasure [19-22].

Environmental Impacts of Bioethanol Production

Due to the rising demand for biofuels, the production of bioethanol has gained significant attention. However, the use of fossil fuels and biofuels is adding to environmental pollution hence causing poor health. To address the challenges related to the unevaluated use of fossil fuels and minimize the harmful effects, the impact and monitoring of greenhouse gas emissions must be monitored. When 1 ton of ethanol production unit was taken into account, it was found that GWP was 585.95 Kg CO_2-eq produced from molasses and electricity. A comparative analysis was carried out for a bioethanol plant that can hold 1,58,000 m^3/annum of bioethanol. The use of cassava exhibits 64.41% and sweet potato exhibits 41.96% return on investment (ROI) in the utilization of 80% plant capacity. The various feedstock cassava resulted in global warming production of 0.2452 Kg CO_2 equivalent, corn of the order of 0.2067 Kg CO_2 equivalent, 2.521 Kg CO_2 equivalent in sweet potato, and 0.2099 Kg CO_2 equivalent in sorghum respectively. All these studies

indicated that starchy biomass feedstock is more sustainable and economical as compared to fossil fuels [18-20].

Economic and Social Considerations

To deal with socio-economic problems, bioethanol has emerged as a worldwide interest. Amongst the variety of renewable energy technologies, cost cost-effective economics of bioethanol is still unfavourable due to food competency, and a large amount of land is required. Apart from the economic viewpoint, other factors like social, and environmental effects are also factors that decide the use of bioethanol as a substitute for fossil fuels. The production and usage of bioethanol are a mixture of technical, social, economic, and political factors. The clear goals and objectives will lead to success in this field [18-20].

CONCLUSION

Bioethanol is produced using agricultural biomass and is an excellent alternative to fossil fuels. It is considered to be sustainable, eco-friendly, and clean fuel. The present review deals with a comparative analysis of bioethanol and fossil fuels with insights into the role of bioethanol in energy production. In the end the socio-economic issues related to the production and commercialization of bioethanol. Out of various feedstock for the production of bioethanol, second-generation lingo-cellulosic biomass is an eco-friendly and sustainable approach to replace fossil fuels. Advancements related to the field of bioethanol production and utilization will pave the way for sustainable development in the energy industry.

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