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Sustainable bio-ethanol production from agro-residues: A review

Anubhuti Gupta, Jay Prakash Verma*

Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India

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ABSTRACT

Due to increasing population and industrialization, the demand of energy is increasing day by day. Simultaneously, the worldwide bio-ethanol production is increasing constantly. The maize, sugarcane and sugar beets are major traditional agricultural crops used as bio-ethanol production but these crops are unable to meet the global demand of bio-ethanol production due to their primary value of food and feed. Hence, cellulosic materials such as agro-residues are attractive feedstock for bio-ethanol production. The cellulosic material is the most abundant biomass and agro-residues on the earth. Bio-ethanol from agro-residues could be a promising technology that involves four processes of pre-treatment, enzymatic hydrolysis, fermentation and distillation. These processes have several challenges and limitations such as biomass transport and handling, and efficient pre-treatment process for removing the lignin from the lignocellulosic agro-residues. Proper pre-treatment process may increase the concentrations of fermentable sugars after enzymatic hydrolysis, thereby improving the efficiency of the whole process. Others, efficient microbes and genetically modified microbes may also enhance the enzymatic hydrolysis. Conversion of cellulose to ethanol requires some new pre-treatment, enzymatic and fermentation technologies, to make the whole process cost effective. In this review, we have discussed about current technologies for sustainable bioethanol production from agro-residues.

Contents

* Corresponding author. Tel.: +91 542 6703555.
E-mail addresses: verma_bhu@yahoo.co.in, jayprakashbhu@gmail.com (J.P. Verma).

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1. Introduction

Due to increasing population, the demand of energy is increasing throughout the world. Currently, the primary source of energy is the fossil fuel and non-renewable sources such as natural gas, oil and coal. These have been used for the production of fuel, electricity and others goods [1]. It has been proposed that such resources would be depleted rapidly near future. The extreme consumption of fossil fuels, especially in large urban areas, has caused more pollution due to release of green house gases (GHGs) during the last few decades. The concentration of GHGs in the biosphere has hugely increased [2]. For subsistence of one's on the earth must require energy, is the most important part for human beings for their growth and development. And it has been deduced that about 13-fold energy consumption increased in 20th century, which is faster than that of increasing population [3–6]. The other interference concludes that about one-quarter of world's population do not access a fraction of energy [7]. We are consuming both renewable as well as non-renewable energies and due to the overconsumption and exploitation of non-renewable energy resources, eventually, all petroleum reserves will be completely depleted; therefore, people are approaching towards the use of renewable source of energy. Consequently, overconsumption of non-renewable energy sources scaling up the price of oil and exacerbating our environment. According to World Energy Council petroleum, natural gas and coal (non-renewable energy sources), which are the good source of energy, collectively contribute nearly 82% of global energy needs and one fifth of the CO_2 emission is due to 60% of petroleum based fossils fuel [8]. Hence to reduce the dependency on these resources a considerable promising shift is needed to utilize the alternative, sustainable as well as renewable sources of energy such as solar, wind, water, biomass and geothermal heat for the energy industry. The chemical industry may depend on biomass as an alternative source in the near future [6]. About 80% world's wind energy is produced by California in the form of Electricity and it has been accounted that Denmark, the world's second largest producer of wind energy, gained 2% of its power through wind turbine in 1990 [9]. Alternative sources of energy are being used in various countries. Biomass like cellulosic agricultural waste is the most abundant biomass on the earth. Using biomass like cellulosic agricultural waste is the potential promising natural renewable, inexpensive, cost effective and sustainable sources used for considerable and commercial production of bio-energy as bio-ethanol. The renewable fuels such as bio-diesel and bio-hydrogen, derived from sugarcane, corn, switchgrass, algae, etc., can be used as petroleum-based fuels in the future as fossil fuels are going to depleted soon due to higher energy consumption.

The limited amount of such alternative energy sources leading us looking for sustainable energy sources i.e., bio-energy. The concept of bio-energy came by dint of pervasive overexploitation of fossils fuel and alternative resources. Bio-energy is the renewable source of energy using natural resources for the production of sustainable bio-fuels. Bemdes et al. [10] estimated that the potential global bio-energy supply range from less than 100 to over 400 EJ/year for 2050 [11]. Biofuel includes solid, liquid and gas and the major biofuels encompass bio-ethanol, biodiesel, biogas, bio-methanol, bio-syngas ($CO+H_2$), bio-oil, bio-char, bio-hydrogen, Fischer–Tropsch liquids petroleum, and vegetable oil, out of which bio-ethanol and biodiesel are liquid transportation fuel, used as an additive source. Bio-ethanol is a gasoline alternate while biodiesel is a diesel alternate to reduce the GHGs emission when blended as an additive. Bio-ethanol produced about 60% from sugarcane and 40% from other crops, while biodiesel from inedible vegetable oil, waste oil and grease and it was estimated that in 2007 about 60 billion liters bio-fuels produced globally [12]. It has been accounted that bio-ethanol could sink about 90% CO_2 and 60–80% SO_2 when blend with 95% gasoline [13,14]. It has also been observed that bio-ethanol is being produced by various biomasses, which are naturally available on the earth. Biomass (bestows just about 14% of world's energy), is the fourth largest source of energy after petroleum, coal and natural gas [15].

Countries across the globe have well thought-out and directed state policies toward the improved and cost-effective utilization of biomass for summit their future energy demands in order to meet carbon dioxide decline targets as specified in the Kyoto Protocol as well as to reduce reliance and dependence on the supply of fossil fuels [16]. Since biomass can be used as a huge source for bio-ethanol production, it is generally used to produce both power and heat, usually during combustion. Recently, ethanol is broadly used as liquid bio-fuel for motor vehicles [17,18]. The significance of ethanol is higher due to various reasons such as global warming and climate change. Bio-ethanol production has been increasing widespread interest at the international, national and regional levels. The worldwide market for bio-ethanol production and demand has entered a phase of rapid, transitional growth. The focus toward renewable sources for power production in various countries of the world has been shifted due to depletion of crude oil reserves. Ethanol has prospective as an important substitute of gasoline in the transport fuel market. On the other hand, the cost of bio-ethanol production is higher as compared to fossil fuels.

The world bio-ethanol production in 2008 was 66.77 billion liters [19]. It has grown to 88.69 billion liters in 2013 and is expected to reach 90.38 billion liters in 2014 [20]. Brazil and the USA are the two major ethanol producing countries of 26.72% and 56.72%, respectively of the world production [19]. Huge scale production of ethanol bio-fuel is mainly depended on sucrose from sugarcane in Brazil or starch, mainly from corn, in USA. Presently, ethanol production depending up on corn, starch and sugar substances may not be popular due to their food and feed value. The price is a significant factor for large scale extension of bio-ethanol production. The green gold petroleum from lignocellulosic wastes avoids the existing struggle of food versus fuel caused by grain dependent bio-ethanol production [18]. Kim and Dale [21] reported that 442 billion liters of bio-ethanol can be produced from lignocellulosic biomass and that total crop residues and wasted crops can produce 491 billion liters of bio-ethanol per year, about 16 times higher than the actual world bio-ethanol production. The cellulosic materials are renewable, low cost and are available in large quantities. It includes crop residues, grasses, sawdust, wood chips, agro-waste etc. Many scientists and researchers have been working on ethanol production from lignocellulosics in the past two decades [16,22–28]. Hence, bioethanol production could be the route to the effective utilization of agricultural residue and wastes. Rice straw, wheat straw, corn straw, cotton seed hair, seaweed, paper, pineapple leaf, Banana stem, Jatropha waste, Poplar aspen; Oil palm frond and sugarcane bagasse are the major agro-residue in terms of quantity of biomass available [21]. For bioethenol production from the cellulosic material of agro-residues, three processes like pre-treatment, enzyme hydrolysis and fermentation are required.