



Conversion of bio resources to bioethanol - A review

Abstract

The increased impact for the assured future of the fuel supply and the negative effect of fossil fuels on the environment, generally greenhouse gas emissions, has put effect on society to observe renewable fuel alternatives. Today, ethanol yield from sugar or grain (starch); is the most common renewable fuel. Appropriately, future large-scale use of an ethanol will most positively have to be depend on manufacture from lignocellulosic materials. This review gives an overview of the new technologies required its accomplishment in recent years to conduct lignocellulosic ethanol towards industrial production. One of the better challenges is to optimize the articulate of process engineering, enzyme engineering metabolic engineering. and fermentation technology, Interest in manufacturing ethanol from biomass in an endeavor to make an alternative ecologically feasible option.

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Keywords

Bio-ethanol; Biomass, Energy balance; Greenhouse gas; Sustainable transportation

Introduction

Bioethanol which are yield mainly from biomass is referred to solid, liquid and gaseous fuels. The bioethanol is classified into three generations as first, second and third based on the chemical and as complex nature of the biomass. The first generation fuels, biodiesel and vegetable oils have been produced from the crop plants and the second, bioethanol and biohydrogen have been produced from agricultural by-products and energy plants which requires fertile lands for growth. The marine resources, seaweeds and cyanobacteria are attractive sources for the third generation biofuels production (biogas, bioethanol and biobutanol) as they produce large biomass in a stipulated period and it doesn't require land for growth (Demirbas *et al.*, 2008 and Kang *et al.*, 2014). Biomass can also be referred as the natural and inexpensive form of storage device for energy, (Castro *et al.*, 2007 and Arthe *et al.*, 2008). Production of bioethanol predominantly depends on terrestrial plants, which have the limitation of cultivable land exploitation, Marine biomass include seaweeds as the new source of bioethanol feedstock produces the highest percentage of biomass in lesser time and therefore such bioresources can be exploited for renewable bioethanol based energy production. The photosynthetic fuel has been initiated as another blooming field of bioethanol. The plants and algae effectively utilize the atmospheric CO₂ and store the energy as biomass which is converted into any form of energy in reverse. The photosynthetic cyanobacteria can convert the CO₂ directly into ethylene a fuel chemical without production of bioethanol.

The advantages of bioethanol over petroleum fuels are (a) they can be easily extracted from the biomass, (b) they are sustainable due to biodegradable property, (c) its combustion based on carbon-dioxide cycle, (d) more environment friendly. The share of biofuel in automobile market will grow rapidly during the next decade because of its environmental merits. This will definitely result from strong growth in the agriculture sector for more production and associated by-products. As per the FAO statistics, India is the highest producer of banana in the world. Being a fruit residue, banana peel contain 30-40 % of total fruit weight and contains carbohydrates, proteins and fiber in significant quantities. Production of ethanol from starchy biomass generally involves different step steps like liquefaction, saccharification and fermentation Pervez *et al.*, (2014).

The main aim of the present investigation using selected lignocellulosic agricultural waste Banana pseudo stem

- * Low cost production of cellulolytic enzymes for saccharification of lignocellulosic materials
- * To improve the industrially important characteristics of yeast strain by uv-mutagenesis.
- * To investigate the bioethanol production from lignocellulosic biomass using control and developed uv-mutated strains.
- * To optimize the key process of pretreatment and hydrolysis that will facilitate the ethanol production.

Bioethanol is providing multiple energy, environmental, and socio-economic benefits, both modern and traditional, ranging from electricity, heat to transportation. Given the broad nature of bioethanol

and the need to embrace the major issues, it would be impossible to encapsulate so much information, and hence it is inevitable that data has to be largely abridged.

Global view

Globally, it has been observed that for future energy systems the estimates of bioethanol are very high. If the share of biofuel in automobile market reaches to its maximum, then the availability of bioresources for biofuel production will become a critical factor. The transition of hydrocarbon economy to carbohydrate economy can be attained with the help of biomass to produce bio-methanol and bioethanol to replace oil-based fuels. The biofuel scenario has produced the reduction in oil imports, growth in GDP, gave an energy ratio and growth in per capita effluence. Every scenario has advantages as the reduction in carbon dioxide emissions, generation of jobs, growth in GDP, the production process energy ratio, etc. (Hassan *et al.*, 2013 and Ghosh *et al.*, 2016).

Bioethanol energy potential

Biomass energy is increasingly seen as entwined with land use, food security, biodiversity, environment, climate change, low carbon economy, sustainable development and so forth. Its deployment is also strongly linked to developments of fossil fuels and other renewable energy sources such as solar and wind, as well as many other technological developments. Bioethanol energy can make a large contribution to the world's energy demand, although with large geographical differences because global natural resources are very unequally distributed; this, however, could partly be mitigated by international bio energy trade. Being made, to estimate the global potential but with huge divergences, which are caused by different assumptions, particularly on the availability of agricultural land for non-food production, crop productivity and availability of residues; support policies, degree of agricultural development, regional and geographical differences, difficulties in estimating traditional applications which barely ever enter official statistics; changes in energy demand, and anxiously on climate change.

Technology for conversion of Bioresources to bioethanol

The removal of energy from seaweed/agricultural biomass can be categorized into two based on the initial drying step. The biodiesel extraction methods using dry biomass could be performed by from beginning to end types, pyrolysis, gasification and finally trans-esterification to biodiesel. The energy production process from wet biomass could be performed by hydrothermal treatments, enzyme hydrolysis fermentation to bioethanol/biohydrogen/biobutanol and anaerobic digestion.

Pretreatment

Physical, physiochemical, chemical and biological processes have been used for pretreatment of lignocellulosic materials. Since lignocellulosic materials are very complex, their pretreatment is not simple either. The greatest method and conditions of pretreatment depend to the highest degree on the type of lignocelluloses.

Enzyme conversion technology

The cell wall of plant biomass contains cellulose molecules deeply fixed in an amorphous surrounding molecules designated as lignin and hemicelluloses. These polymers are attached strongly to each other molecules with non-covalent force and by covalent cross-links and made a complex material called lignocellulose, and it is a major part of the plant cell approx. 90% of the dry weight. The enzymatic hydrolysis has been promoted as a potential process for the conversion of biomass (Wati *et al.*, 2007).

The major function of the cellulase includes hydrolysis as polymer cellulose to monomer glucose (Zhuang *et al.*, 2001 and Gan *et al.*, 2003). The complete degradation of cellulose molecule would be achieved by the action of all three enzymes. The first enzyme involved in the degradation of cellulose is endoglucanase (EG) (1, 4- β -D-glucan-4-glucan-hydrolases; EC3.2.1.74) which acts on glycosidic bonds appeared interior of the cellulose molecule randomly. The reducing or non-reducing ends of cellulose are then further degraded by exoglucanase (EC 3.2.1.91 and EC 3.2.1.74) and resulted in either cellobiose or glucose. The complete hydrolysis process has not occurred without the enzyme β -glucosidase (BGL) (EC 3.2.1.21) which acts on cellodextrins, and cellobiose resulted in the prior enzymes actions and converted into glucose. However, a breakthrough in the investigation of cellulose digestion processes for different biomass will have an enormous impact on the world fuel supply and economy (Louime *et al.*, 2008). Enzymatic degradation of hemicellulose in the biomass focuses more on xylan, which is the major hemicellulose in wood from angiosperms. The xylan molecule has a complex structure and contains xylose, L-arabinose, and D-glucuronic acid, among others. The xylan molecule also requires the group of enzymes for complete degradation.

Microbes conversion of bioethanol

The conversion enzymes production for bioethanol was tried by researchers for many decades. The number of wild-type bacteria, actinomycetes, and filamentous fungi has been reported to produce extra cellular hydrolytic enzymes when grown on specific substrates like cellulose/hemicellulose substrates (Ishaque *et al.*, 1980 and Kluepfel *et al.*, 1986). Consequently, the advanced biotechnological research focuses on genetically engineered bacteria for the hyperproduction of the enzymes (Hong *et al.*, 2007 and Kotaka *et al.*, 2008). New organisms search for hydrolytic enzyme production has also been continued in the bioethanol research. Though, the extracellular enzyme system of the *Trichoderma* sp. was well studied and commercial level enzyme production has been investigated on the same organism, the investigation on cellulase production from other microbes could also offer the route for its usage in the hydrolysis of the polysaccharide. In last decades, number of research work has been initiated and continued on effective utilization of agro-industrial biomass available in various sectors like apple pomace, coconut oil cake, cassava wastewater, grape pomace, ground nut shell waste, rice straw, wheat straw, wheat bran, sugarcane bagasse, banana pseudo stem, coir pith, bamboo, etc. to produce cellulase and xylanase by

fungi like *Aspergillus awamori*, *A. niger*, *A. fumigatus*, *A. heteromorphus*, *A. nidulans*, *A. oryzae*, *A. terreus*, *Melanocarpus sp.* MTCC 3922 *Penicillium sp.*, *Rhizopus stolonifera*, *Scytalidium thermophilum*, *Trichoderma sp.*, etc. The enzyme production has been continued with both solid state (SSF), and submerged (SMF) fermentation and many reports investigated SSF would be the best as it cost effective and natural state of fermentation. The researchers described the advantages of SSF on enzyme production over the SMF, even though for laboratory level, SMF is a preferred method of optimization. Fermentation also referred to a biological process in which sugars such as glucose, fructose, and sucrose are converted into cellular energy and thereby produce ethanol, butanol, and hydrogen. A variety of microorganisms includes bacteria, yeast, or fungi, ferment carbohydrates to energy products. Bacteria have drawn special attention of researchers because of their speed of fermentation. In general, when compared to yeast, bacteria require less fermentation time. All microorganisms have limitations: either in the inability to process both pentoses and hexoses, the low yields of the end product Lynd *et al.*, (1996).

Challenges in the bioethanol production: Economical pretreatment

An effective and economical pretreatment should convene the following requirements: (a) creation of unconsidered cellulosic fiber for enzymatic reaction, (b) avoiding destruction of hemicelluloses and cellulose, (c) avoiding the formation of possible inhibitors for hydrolytic enzymes and fermenting microorganisms, (d) minimizing the energy demand, (e) reducing the cost of size reduction for feedstocks, (f) reducing the cost of material for building of pretreatment reactors, (g) producing less residues, (h) consumption of slight or no chemical and using a cheap chemical. Several methods have been proposed for pretreatment of lignocellulosic materials. These methods are classified into "Physical pretreatment", "Physico-chemical pretreatment", "Chemical pretreatment", and "Biological pretreatment" (Berlin *et al.*, 2006 and Karimi *et al.*, 2006).

Cost of enzymes

Development of efficient hydrolytic enzyme production is required to reduce the cost of bioethanol production. Since the high cost of commercial enzymes, the bioethanol production at large scale is uneconomical for commercialization for the fuel demand He *et al.*, (2014).

Fermentation efficacy

It has been reported that genetic engineering and new screening technologies will bring bacteria and yeast that are capable of fermenting both glucose and xylose (US Department of Energy 2003). Mid-to long-term technology development will improve the fermentation efficiency of the organism (yielding more ethanol in less time), as well as its resistance, requiring less detoxification of the hydrolysate (Sonderegger *et al.*, 2003 and Wooley *et al.*, 1999).

Sustainable feedstock

Bioethanol is being a prime and largest sustainable source of energy in the world. The coal, petroleum and natural gas are the largest available form of energy but not sustainable source though

it was providing 14% of the world's primary energy. The global production of plant biomass, with 90% of lignocelluloses, amounts to about 200×10^9 tonnes per year. The primary biomass $H^8-20 \times 10^9$ tonnes can be potentially used for energy production which is four fold higher than annual energy consumption of the world (Hall *et al.*, 1998). They are often locally available, and with the developments in research and the process of conversion becomes achievable to convert the biomass into secondary forms of energy carriers. However, the biomass resource requires examination for valuable utilization and the analysis mainly based on its spatial and temporal availability, cost of transportation and storage of these organic materials in large quantities (Lin *et al.*, 2006). This sustainable biomass is a proven basis for the invention of greener technology for sustainable energy production. The developed sustainable green energy technologies from solar and wind are being placed under "renewable energy" which will be a beginning of modern energy technologies (Lin *et al.*, 2006 and Rajoka *et al.*, 2005) and can contribute to sustainable development. The largely promising sustainable and rich biomass is lignocellulose acts as a chief source of fermentative biofuel production (Rashid *et al.*, 2008) and are reported unique merits of biomass energy such as -

- 1) performing a key role in reducing the emission of greenhouse gas via utilizing biofuels as the way reducing the usage of fossil fuel,
- 2) first the largest source of sustainable biomass in the world leads sustainable biofuel technology
- 3) the biomass generated by the energy plants would create new employment opportunity for rural marginal farmers significantly social sustainability
- 4) seems to be the only alternative energy for near future and bioprocessing give way to disposal problem Lin *et al.*, (2006).

Sustainable production

The sustainability of the current energy systems is a big question mark because of economic, equity and environmental issues. To protect the land, communities, and biodiversity various sustainability initiatives, as well as the number of schemes, is being implemented for biofuels. The countries like Brazil and Netherland have taken initiatives for sustainable development of biofuels from crops and agreed on cooperation for biofuels production. In the US the Government funds are provided to accelerate the research and development of biofuels market. In the world's energy production China leads the third place next to Brazil and US. The Government of China is primarily focusing on the production of ethanol on the industrial scale. India has "National Biofuel Policy" to meet the 20% demand for diesel by replacing it with biodiesel. They have also proposed to replace 10–20% of gasoline with bioethanol (Hassan *et al.*, 2013 and Kim *et al.*, 2011). Sustainability, policy and commercial aspects of biofuels.

Sustainable energy

Bioethanol has been emerged as the important source for sustainable fuel and are considered for progress in finding new energetic resources, improving air quality and limiting greenhouse gas emissions. For economic and environmental sustainability of

biofuels carbon effort and renewable biofuels are necessary. As people always need fuel for heating, living, transportation purpose, etc. the desire for production of fuel has been increased tremendously. The global production of oil and gas has been reached to its saturation point though the alternative source for the sustainable production of oil and gas being in the pipeline. Hence, as an alternative option to fossil fuels, the biofuel is considered as a leading and sustainable energy source in future which can reduce vehicle emissions, increase the supply of sustainable energy and afford income for farmers as sustainable bioresources (Ghosh *et al.*, 2016 and Kim *et al.*, 2011).

Bioethanol policy and analysis

In India, the biofuel policy and regulation on the utilization of bioresources for biofuel production process is proposed by MNRE, New Delhi, India. However, the implementation of biofuel policy requires Research and Development efforts to attain an economic bioethanol production. Therefore, large-scale utilization of bioresources for biofuel production would be a new venture in India. Energy is an essential input for the economic development of the country. In India, the national policy on bioethanol framed in December 2009 with the intent of implementing the usage of bioenergy as a motor fuel with the blending ratio of 20% by 2017 which is derived from the biomass and other related renewable sources. The detailed report of policy developed by Indian Government was given in the ministry of new and renewable energy (MNRE) web (Raman *et al.*, 2014) for the people of rural areas in developing countries to get new opportunities in oil imports from the biofuels perspective. Hence, the energy policies of economically developed countries include the integration of market of the private sector and regulatory frameworks for keeping competitiveness. The competitiveness involves liberalization of transportation, energy production, distribution, oil and gas market, and electricity. On the whole, the central policy for biofuels is focused for protection of the environment, higher efficiency in the corporate sector and job creation (Demirbas *et al.*, 2008 and Ghosh *et al.*, 2016).

Bioethanol production

Bioconversion of organic solid wastes instead of food source using SSF for bioethanol production is suitable and attractive for sustainability and renewable energy production. Several authors have proved the efficiency of SSF in the reduction of capital costs and consumption of energy and water during bioethanol production. The process also offers a valorization of organic solid wastes, the elimination of sugar extraction and additional separation steps, production of higher yield and a simplification of the operation by carrying out the hydrolysis and the fermentation together. Both yeast and fungi are the most reported microorganisms involved in bioethanol production due to their convenient environment in SSF. *Saccharomyces cerevisiae* yeast has been extensively reported as a responsible organism for the bioconversion of solid wastes (apple pomace, grape pomace, sugar beet pomace, potato peel, sweet sorghum stalks, sugarcane bagasse, food waste, etc.) into bioethanol production under SSF (Kanwar *et al.*, 2012, Rodríguez *et al.*, 2010, Chintagunta *et al.*, 2016, Du *et al.*, 2014, Uçkun *et al.*,

2015, Liu *et al.*, 2015, Ang *et al.*, 2015). and Du *et al.*, 2014 confirmed the feasibility of scaling up the bioconversion of sweet sorghum stalks by *S. cerevisiae* from 500 mL to a 127 m³ rotary drum fermenter and subsequently in a 550 m³ rotary drum fermenter with 88% of relative theoretical ethanol yield in less than 20 h. Anjani *et al.*, 2013 presented an interesting integrated bioconversion of potato peel by SSF for the production of bioethanol and manure by employing yeast and fungi (*Aspergillus niger*, *A. variabilis*, and *S. cerevisiae*) to achieve zero waste generation. In Asian regions, palm oil trunk (Ang *et al.*, 2015) rice straw (Thomas *et al.*, 2016, Suresh *et al.*, 215) and banana pseudo stem (Ingale *et al.*, 2014). were successfully utilized to produce bioethanol with high yield (84%) by *Aspergillus sp.* and *T. reesei* through SSF. Apart from yeast and fungi, other attempts have been made using bacterial strains to produce bioethanol that resulted in efficient bioconversion. In fact, an integrated bioconversion process of organic solid wastes (switchgrass and sweet sorghum bagasse) by *Clostridium phytofermentans* (Jain *et al.*, 2013) and *Zymomonas mobilis* (Yu *et al.*, 2014, Yu *et al.*, 2016). Comparatively resulted in a high bioethanol yield through SSF.

Future scope

It has been seen by many people that bioethanol is a cleaner way for the transport sector to meet all the energy needs. During combustion in the engine, we achieve environmental benefits such as less carbon dioxide emissions correspond to the amount that was sequestered from the atmosphere. This results in the formation of the closed carbon cycle. In spite of the benefits which characterize the use of biofuels, it is necessary to keep in mind that the production and end use of bioethanol have the serious impact on the environment such as destruction of the forest, increase in soil degradation, reduction in food production, use of a large amount of water. In developing nations like India, implementation of alternative fuel options is a prime concern to meet up the future oil demands. As seaweeds are most diverse in Indian coasts, they can be exploited for this purpose. Seaweed cultivation in India is not a new process as they are cultivated from the past as a source of food, food derivatives, vitamins, proteins, raw material for many agar-agar and algin based industries. For the production of bioethanol, they have to be cultivated in large-scale, and processes for extraction are to be studied in detail to attain nations' economical needs.

The future of global bioethanol production will depend on the number of interrelated factors and their profitability. The use of bioethanol is being promoted by many Governments all over the world. In initial nations like India, implementation of alternative fuel options is a prime concern to meet up the future oil demands. It is obvious that each country will have to utilize the available biomass and cultivate oil-producing crops which are suitable for their climate. For the production of bioethanol, seaweeds have to be cultivated in large-scale, and processes for extraction are to be studied in detail to attain nations' economical energy needs. There is a much potential for biofuel market which has been accepted globally, and the use of bioethanol as alternate to fossil fuels still requires technological development to reduce the cost of production and

emission of greenhouse gas and to increase the feasibility. Promotion of biofuel as alternate fossil fuel requires global acceptance and development of efficient biofuel-driven engines. Therefore, for strengthening the global economy, mitigating climate change and enhancing environmental quality sustainable biofuel production will play a positive role. And hence both industry and environment are benefited from their early identifications and refinement in the field of different fuels.

Acknowledgments

The authors are grateful to the authorities of North Orissa University (Dept of Biotechnology) and to the Director CSIR, IMMT (Environment and sciences dept) for providing laboratory facilities to carry out the work.

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