Overview of current perspectives, potential issues & future prospects of ethanol production from various substrates

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Abstract

Ethanol is been known to mankind from a long time ago. Ethanol is a colorless, volatile, flammable oxygenated hydrocarbon having general formula C2H5OH.Extensive use of fossil fuel has increased the pollution and the concentration of greenhouse gases which is leading to global warming. Now days, as because of the over growing population and the increasing demand of the fuel, ethanol is the most common alternate fuel and can be produced on a fair scale, representing a sustainable substitute for gasoline. Ethanol is important for biological and commercial use. Ethanol is majorly being used as solvent and as for sterilization purpose. It is also used as an important component in various syrups such as cough syrups and various tonics. There are various methods of production of ethanol. It was traditionally being produced from the sugarcane molasses, using the fermentation technique. With the passage of time many different substrates and vivid species of microorganisms are being used, till date, for the production of ethanol. This includes the starch crops to the banana peels and producing the bioethanol even from the waste containing the lignocellulosic waste and even the agricultural waste. Industries aims for producing high amount of ethanol in a relatively low price and many scientists are trying to find such substrate which will give the maximum production of ethanol. This paper provides a brief review about the comparison of the yield of ethanol and also has enlisted various types of substrate and there conversion rate which will give the clear idea of best suitable substrate to be used for commercial production of ethanol. Some of the major commonly faced problems regarding the commercial production of ethanol have also being discussed. This also focuses on the future improvisation, the future aspects, and the optimization of ethanol production and its overwhelming boom in biotech industry.

Akshay Bhatt* | *Bhuvnesh Balki* | *V.P. Bhange

Department of Biotechnology, Priyadarshini Institute of Engineering & Technology, Nagpur- 19.

akshaybhtt38@gmail.com, bhuvnesh.balki@gmail.com, vivekbhange@gmail.com

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Introduction

The importance of renewable energy sources is increasing day by day and finding its importance not only in protecting the environment but also fulfilling the energy needs and thus reducing dependence on fossil fuels. Ethanol is one of the bio-energy sources with high efficiency and low environmental impact. Ethanol is the most common biofuel worldwide. The raw materials used for ethanol fermentation can be classified into three main types which are cellulosic material, starches, sugar. The sugars can be directly converted to the alcohol by fermentation whereas the starch needs to be converted into fermentable sugar and the alcohol is obtained by fermentation. In case of the cellulosic materials, it needs to be hydrolyzed first by using pretreatment which are economical. For lab scale fermentation enzymatic hydrolysis can be used. Thus the fermentable sugar so formed from starches and cellulose can be converted to alcohol by using microorganism. Although conventional fuel ethanol is derived from grains such as corn and wheat competing as a food source for humans, the cereal industry produces vast amounts of residue that has little use today.

The first generation of ethanol production used corn as a substrate, later corn was considered as a feedstock lead to the second generation of production of ethanol which used microorganisms and different wastes as substrates (Grassi, 2009). Although corn-based and sugar based-ethanol are promising substitutes to gasoline production mainly in the transportation sector, they are not sufficient to replace a considerable portion of the one trillion gallons of fossil fuel presently consumed worldwide each year (Bell and Field, 2006). Furthermore, the ethical concerns about the use of food as fuel raw materials have encouraged research efforts to be more focused on the potential of inedible feedstock alternatives (Sun and Cheng 2002). Lignocellulosic biomass materials constitute a substantial renewable substrate for bioethanol production that do not compete with food production and animal feed. These cellulosic materials also contribute to environmental sustainability (Demirbas, 2003).

Various types of substrates are available for the ethanol production. This includes the commonly used sugarcane molasses to banana peel and corn. Research for using different substrates is gaining huge importance for obtaining better and cheaper alcohol. Different substrates can be used for the production of ethanol. The substrates can be selected on the basis of availability, cost and processing methods. Cheap substrates are mostly preferred so as to reduce the cost of production. At the same time the cost of pre-treating the substrate for releasing fermentable sugar is also considered, as it directly affects the operational cost. Vivid species of microbes are also being used to improvise the quality and quantity of ethanol production.

As ethanol is a promising alternative to fossil fuels, it become necessary to increase the production methods of this biofuel. Our objective of this paper is comparative study of production of ethanol from various substrates, its current perspectives, potential issues, future prospects, advantages, disadvantages and its overwhelming boom in biotech industry.

Comparative Study of Ethanol Production from Various Substrates

Selected strains of the yeast Saccharomyces cerevisiae are commonly employed for fermentation. This is because (a) they grow vigorously, (b) they have high tolerance for alcohol and (c) they have a high capacity for producing a large yield of alcohol. Before fermenting a product pre-treatment is done, pre-treatment is the chemical reaction that converts the complex polysaccharides in the raw feedstock to simple sugars. In the biomass-to-bioethanol process, acids and enzymes are used to catalyze this reaction. Fermentation is a series of chemical reactions that convert sugars to ethanol. The fermentation reaction is caused by yeast or bacteria, which feed on the sugars. Ethanol and carbon

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dioxide are produced as the sugar is consumed. Ethanol is then separated from remain constituent. Finally, alcohol is purified with the help of rectifying columns and stored in bonded warehouses .Ethanol is the most widely used bio-fuel worldwide. Production of bio-ethanol from various organic substrates such as biomass, simple sugars, starch etc. is a very beneficial for reduction in the usage of crude oil and environmental pollution. Various technologies for the production of ethanol using different types of substrates are under development and need to be demonstrated commercially. The table 1 provides the study of production of ethanol from various substrates:

Table 1: Ethanol Production from Various Substrates

Sr No.	***Name of substrate***	***Technique used***	Time taken	pH	Temp.	Yield produced	Ref.
01	*Wheat straw*	*a) simultaneous saccharification & fermentation*	*120 hrs*	*7.0*	*35^{0}C*	*41.6g/1*	*Saha, et.al, 2011.*
		b)sequential statistical optimization	*--*	*5.5*	*30^{0}C*	*16.4g/1*	*Singh & Bishnoi, 2013*
		c)simultaneous hydrolysis & fermentation	*12hrs*	*7.0*	*35^{0}C*	*41.8g/1*	*Saha et.al, 2011*
02	*Maize*	*wet oxidation*	*20 mins*	*-*	*121^{0}C*	*30.8kg/ 100kg dry maize*	*Popiel et al, 2008.*
03	*Sorgham*	*Very high gravity fermentation*	*-*	*-*	*-*	*0.45 g/l*	*Laopaiboon, et.al, 2009.*
04	*Sugarcane*	*Enzymatic treatment*	*-*	*5.5*	*37^{0}C*	*18.2 & 16.3 g/l*	*Asgher et al, 2013.*
05	*Lignocellulose*	*Simultaneous saccharification& fermentation*	*-*	*-*	*-*	*3.9 g l−1 h−1*	*Alriksson et al. 2011*
06	*Cassava*	*Thermophilic fermentation*	*84hrs*	*-*	*-*	*8.83 ± 0.31 g/ l*	*Li & Zhu, 2011*
07	*Grape*	*Fermentation*	*-*	*-*	*121^{0}C*	*20.84 g/l*	*Egüés et al.,2013*
08	*Kinnow waste & banana peels*	*Simultaneous saccharification& fermentation*	*48hrs*	*-*	*30^{0}C*	*26.84 g/l*	*Sharma et al., 2007*

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Sr No.	Name of substrate	Technique used	Time taken	pH	Temp.	Yield produced	Ref.
09	Corn	Fermentation	72hrs	-	-	61.8 g/l	Shigechi, et.al,2004
10	Sweet potato	Simultaneous saccharification& fermentation	60hrs	-	31.3^{0}C	14.92%(v/v)	Lim, et.al,2013
11	Cellulose	Simultaneous saccharification& fermentation	50hrs	-	-	16.5 g/l	Yasuya et.al 2002
12	Marine green algae	Dark fermentation	24hrs	-	30^{0}C	450 µmol/g-dry wt	Ueno et al.1998
13	Thermotolerant yeast	Immobilization	72hrs	-	-	3.03±0.02 v/v	Dahiya and Vij.2012
14	Litchi fruit	Fermentation	120hrs	5.0	25^{0}C	3.50% (w/v)	Singh &Kaur, 2009
15	Amla	Fed batch fermentation	120hrs	5.0	27^{0}C	16.1%	Soni et.al,2009

Current Perspectives of Ethanol Production

Bioethanol market is expected to reach 100x109 liters in 2015. The largest producers in the world are the US, Brazil, and China. In 2009, US produced 39.5x109 liters of ethanol using corn as a feedstock while the second largest producer, Brazil, created about 30x109 liters of ethanol using sugarcane. China is a country that has invested much in the production of ethanol, and is nowadays one of the largest ethanol producers (Ivanova et.al,2011).

Ethanol contains 35% oxygen, which results in a complete combustion of fuel and thus lowers the emission of harmful gases. Moreover, ethanol production uses energy from renewable sources only; hence, no net carbon dioxide is added to the environment, thus reducing green-house gas emissions. It has also been well established now that ethanol increases the octane number, decreases the Reid vapor pressure and produces fuel with clean burning characteristics (Dhillon, et.al, 2007). Moreover, neat (unblended) ethanol can be burned with greater efficiency, and is thought to produce smaller amounts of ozone precursors (thus decreasing urban air pollution), and is particularly beneficial with respect to low net CO2 put into the atmosphere.

The increasing demand for various industrial purposes such as alternative source of energy, industrial solvents, cleansing agents and preservatives, has necessitated increased production of ethanol (Brooks,2008). Furthermore, ethanol by fermentation offers a more favorable trade balance, enhanced energy security, and a major new crop for a depressed agricultural economy. Ethanol is considerably less toxic to humans than is gasoline (or methanol). Ethanol also reduces smog formation because of low volatility; its photochemical reactivity and low production of combustion products. Furthermore, low levels of smog-producing compounds are formed by its combustion (Wyman and Hinman,1990). In addition, the low flame temperature of ethanol results in good engine performance.

Currently, bioethanol is being commercially produced only from edible feedstock such as cornstarch and sugarcane juice.The use of fuel ethanol has been quite successful in Brazil, where it is

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being produced at a very low cost by fermentation of sugarcane. In the US, corn is the dominant biomass feedstock for production of ethanol, and in the EU, straw and other agricultural wastes are the preferred types of biomass for ethanol production (Raposo, et.al, 2009). These bioethanol production systems pose a concern about competition with food and feed supplies. To avoid this competition, bioethanol production from non-edible lignocellulosic biomass such as wheat straw, rice straw, bagasse, corn stover, wood, peels of fruits and vegetables is attracting keen interest. The current production and use of bioethanol processes are a starting point. It is believed that the next generational change in the use of bioresources will come from a total integration of innovative plant resources, synthesis of biomaterials, and generation of biofuels and biopower.

Potential Issues Related to Ethanol Production from Various Feedstocks

The rapid expansion of ethanol production from sugarcane and various other feedstocks has raised a number of questions regarding its consequences and sustainability. The sugar-based feedstocks such as (sugarcane, sweet sorghum, sugar beets, and molasses) are used for ethanol production. Cellulose raw materials are the most abundant feedstocks on the Earth, but sugar-based feedstocks appear to contribute actually effectively to ethanol production in the world. Also, they are present at lower production cost, mainly ethanol from sugarcane, where the feedstock contributes with 60–70% of the production cost. The processing of these feedstocks is quite similar except for the sugar extraction stage. The energy balance and GHG emission reduction potential are very much positively influenced by the availability of residues that are used as fuel for the processing plant, such as the cases of sugarcane and sweet sorghum, and by the high agricultural yields, as are the cases of sugarcane and sugar beet.

Positive impacts are the elimination of lead compounds from gasoline and the reduction of noxious emissions. There is also the reduction of CO2 emissions, since sugarcane ethanol requires only a small amount of fossil fuels for its production, thus being a renewable fuel. These positive impacts are particularly noticeable in the air quality improvement of metropolitan areas but also in rural areas where mechanized harvesting of green cane is being introduced, eliminating the burning of sugarcane.Negative impacts such as future large-scale ethanol production from sugarcane might lead to the destruction or damage of high-biodiversity areas, deforestation, degradation or damaging of soils through the use of chemicals and soil decarbonization, water resources contamination or depletion, competition between food and fuel production decreasing food security and a worsening of labor conditions on the fields (Fortaleza-Ceará).

Studies indicate that current starch based ethanol technologies are much less petroleum-intensive than gasoline but have greenhouse gas emissions similar to those of gasoline. However, many important environmental effects of biofuel production are poorly understood. New metrics that measure specific resource inputs are developed, but further research into environmental metrics is needed. Nonetheless, it is already clear that large-scale use of ethanol for fuel will almost certainly require cellulosic technology. The escalation of global warming has forced the public to rethink how policies of energy utilization can ever sustain human activities. Over 40% of fossil energy use is linked to the transportation sector, which is deemed as the major culprit that continues to worsen our earthly environment. Many measures have been proposed and taken in order to minimize emission of greenhouse gases. Ethanol, made by Saccharomyces yeasts through fermentation, is currently the world's largest fermented liquid fuel. The discharge of carbon as CO2 during its production and use is essentially zero when the fixation of carbon dioxide by the plant is considered, and ethanol is therefore a green and sustainable alternative energy to partially replace or augment petroleum.

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Future Prospects of Ethanol Production

Ethanol has a long history being one of the most versatile and frequently used substances available. In the near future, the need of producing naturally-based fuels, such as ethanol, could have potential impact on the various developing countries and boost their agricultural industries to the point where they can become self-reliable. The worldwide interest of moving from a petroleum-based system to an ethanol-based system seems to be endless.Ethanol is found to be a positive source of energy - giving almost sixty-five percent more than the energy that it takes to produce it. Ethanol seems to be the practical and a very viable solution to many of the current energy issues facing inthe world as the earth's precious resources are being quickly depleted. The major obstacle in the usage of ethanol as a fuel is its production cost. As ethanol production ispresently dependent on agricultural feedstock, which comprise anywhere from 30-60% of the total cost of production, minimizing feedstock costs are responsible in making ethanol fuels more affordable to consumers.

The future of ethanol fuels appears to be bright, as countries around the world have begun to pursue aggressive ethanol strategies in recent years.Environmental externalities should continue to be incorporated into policy consideration; ethanol fuels are likely to become an increasing and the most attractive fuel alternative in the foreseeable future. A combination of well-reasoned governmentpolicies and technological advancements inethanol fuels could guide a smooth transitionaway from fossil fuels to ethanol fuel use in the transportation sector. (Garba et al.,2009).

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TERRE Policy Centre

Field Address :
Pandit Ajgaokar Scheme,
Khandobacha Mal, Bhugaon,
Pune - 411042, Maharashtra (India)

Office Address:
22 Budhwar Peth,
Pune 411002, Maharashtra (India)

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