A Gateway to All Post Graduate Courses

An MHRD Project under its National Mission on Education through ICT (NME-ICT)

Subject: Biotechnology

Production of Courseware

-Content for Post Graduate Courses

Paper No. : 05 Environmental Biotechnology

Module : 18 Conversion of Sugar to alcohol; Gasohol

Principal Investigator:	Dr Vibha Dhawan, Distinguished Fellow and Sr. Director The Energy and Resouurces Institute (TERI), New Delhi
Co-Principal Investigator:	Prof S K Jain, Professor, of Medical Biochemistry Jamia Hamdard University, New Delhi
Paper Coordinator:	Dr Sanjukta Subudhi, Sr. Fellow, The Energy and Resouurces Institute (TERI), New Delhi
Content Writer:	Dr Ranjeet Singh, Associate Fellow, The Energy and Resouurces Institute (TERI), New Delhi
Content Reviwer:	Dr Sanjukta Subudhi, Sr. Fellow, The Energy and Resouurces Institute (TERI), New Delhi

Description of Module	
Subject Name	Biotechnology
Paper Name	Environmental Biotechnology
Module Name/Title	Conversion of Sugar to alcohol; Gasohol
Module Id	18
Pre-requisites	
Objectives	About Gasohol Feedstocks for bioethanol production Bioethanol as fuel Advantages and concerns of gasohol as fuel
Keywords	Gasohol, Ethanol, Environment friendly, Mircobial Fermentation, Lignocellulose

1) Learning Objectives:

This module is intended to apprise students about the developments in the area of conversion of sugar to alcohol for the formation of gasohol. Sugar to alcohol conversion technology was developed as an alternative clean energy options to reduce the population's dependence on fossil fuels, and to minimize greenhouse gases emission in environment. This module will discuss the major challenges in technical, biological, environmental as well as social factors responsible for gasohol production technology and its usages as a fuel as well as summary on the current gasohol programs and policies.

2) Introduction

2.1) What is Gasohol?

Gasohol is an alternative fuel consisting of one part ethyl alcohol (also called grain alcohol) mixed with nine part of pure gasoline (unleaded petrol). It is widely considered as an alternative fuel for motor vehicles. It has been approved to be used as fuel for vehicles in many countries or as alternative energy from biological processes. Gasohol releases the same amount of energy as regular gasoline and can be easily used in most of the modern vehicles with little modification in the engine with slight differences in performance. Gasohol have high octane level and it produces pollutants at very lower levels in compare to pure gasoline. It is useful in reducing the population's dependence on petrolium oil, and has lower CO_2 emissions by up to 30 %. Gasohol is one of the high demanded alternative automobile fuels in the world (U.S.A & Brazil are the largest producers and consumers of ethanol and gasohol). Therefore, the increase in consumption of conventional fuels as economies are growing and the the depletion of few of such fuels has prompted us to search for an alternatives clean energy globally.

2.2) Why ethanol for gasohol production?

Ethanol or ethyl alcohol is a colorless liquid with a characteristic odor. Generally it is being produced for blending with gasoline for gasohol production, because ethanol is fuel efficient and when it mixed

with unleaded gasoline, it increases the octane level of fuel and improves combustion as well as extends the supply of gasoline to engine. Also ethanol being a renewable energy source, hence it is an eco-friendly additive. Moreover, gasohol production or its combustion does not produce amy greenhouse gases or harmful pollutants and even ethanol usages reduces the emission of many particulate matter and SO_2 as well as decreases the discharge of carcinogenic benzene and butadiene and thus reduces the cancer by 50%. It also decreases the emission of hydrocarbons that are responsible for depletion of ozone layer.

2.3) How ethanol is produced for Gasohol: Ethanol has been produced since past many years through the biological process. For gasohol formation, ethanol is produced by fermentation of crop grains, hence, also called grain alcohol. The most easily available grains that have been in used for ethanol production are corn, sugarcane and wheat. Simple sugars are the raw material for ethanol production. Fermentation process is a biological process to convert the simple sugars (e.g. glucose, fructose) with the help of enzyme (Zymase) are converted into ethanol along with release of cellular energy and CO_2 as intermediate products. Ethanol fermentation is an anaerobic process performed by several microorganisms in the absence of oxygen such as yeast and certain bacteria, convert simple forms of sugars derived from plant biomass into bioethanol through a process called alcoholic fermentation. In fermentation, ethanol retain much of the energy that was originally present in the sugar, describing why ethanol is an excellent fuel source. All ethanol used in beverage industries are still made by this process.

Conversation mechanism for ethanol production

$$C_6H_{12}O_6 \quad ====> \quad 2(CH_3CH_2OH) + 2(CO_2) + \text{Energy (stored in ATP)}$$

$$\text{Sugar (Glucose)} \xrightarrow{\text{Zymase}} \text{Ethyl alcohol} + CO_2 + \text{Energy}$$

2.3) Raw materials for gasohol Production: Almost any plant parts can be used as substrate for bioethanol fermentation. However, the choice of feedstock depends on certain factors e.g. processing taime taken for the various substrate available, climate conditions, area, soil composition and content of sugars in the chosen feedstock. Generally crops such as sugarcane, corn, grain or left over crop residues are used as feedstock but primarily, three types of raw materials are generally being used for this purpose, sugary crops, starchy crops, and cellulosic materials (lignocellulosic residues). These raw materials are first chemically treated to break down the complex lignocellulosic components into simpler sugars molecules. Then enzymatic step hydrolyses the complex sugars to simple sugar molecules that get anaerobically fermented by certain microorganisms to produce ethanol. A second type of gasohol can also be produced with methanol (or wood alcohol) and gasoline in the percent ratio of 97: 3 respectively.

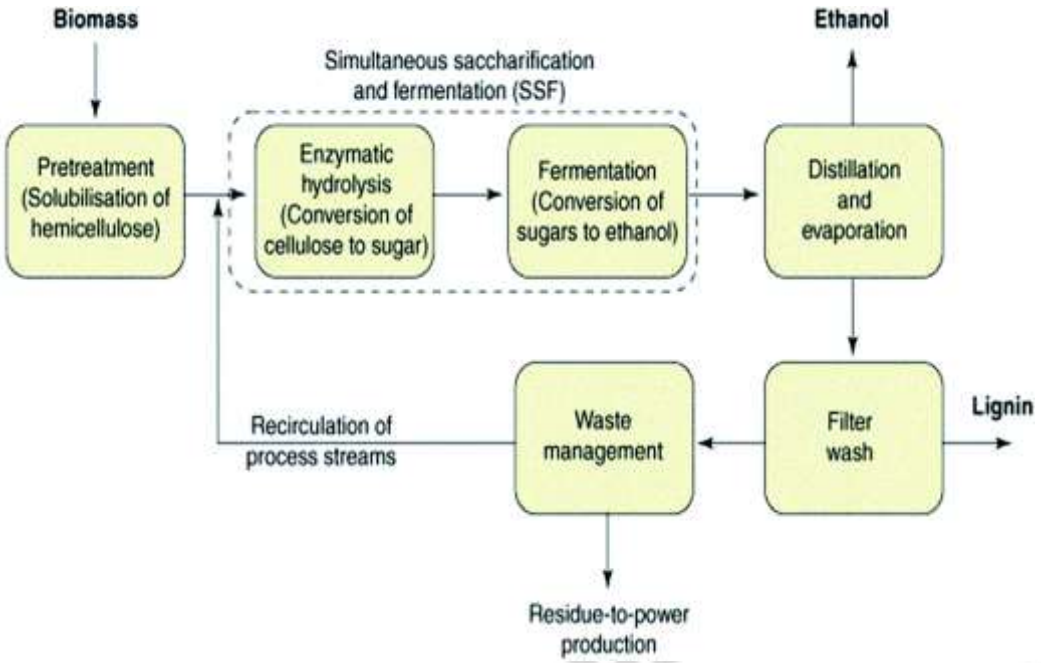

Figure 1: Process flow of biomass to ethanol generation (Source: http://pubs.rsc.org/services/images/RSCpubs.ePlatform.Service.FreeContent.ImageServie.svc/ImageService/Articleimage/2015/RA/c5ra12735a/c5ra12735a-f5_hi-res.gif)

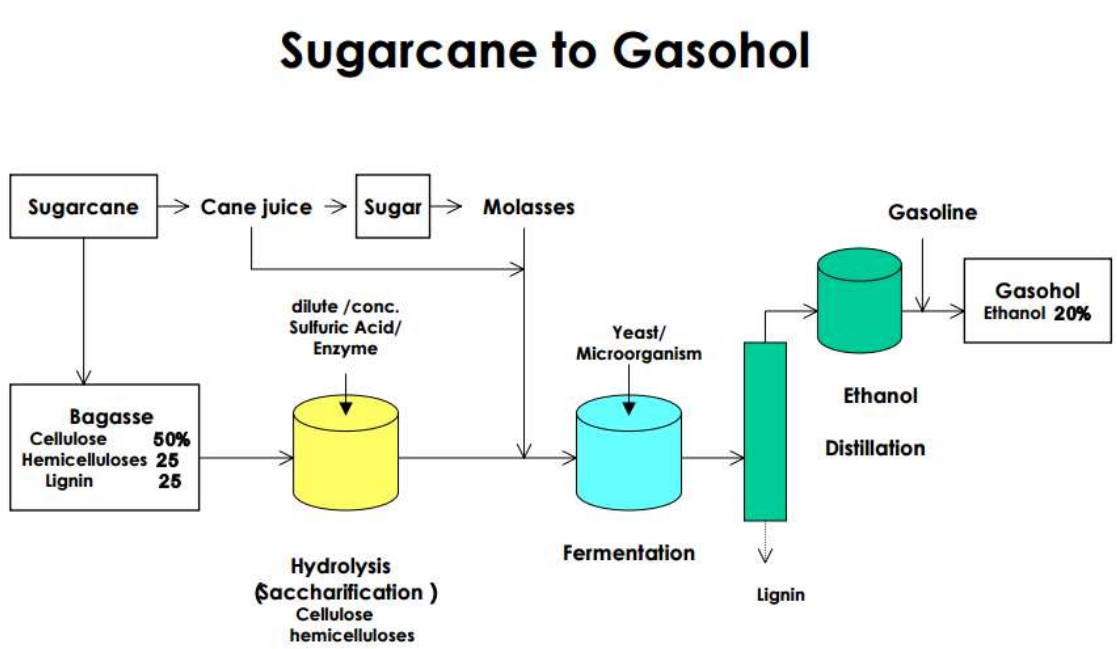

Figure2 : Flow diagram of the ethanol production process (**Source:** http://www.ee-design.net/imgEED/IMGCUT/topics/topics20061214/sugarcane.gif)

2.4) What is E number in Gasohol?

The blending percentage of ethanol in gasohol vary, therefore, the ethanol in gasohol normally has an "E" number which shows the amount of ethanol in gasohol by its volume, e.g. E10 consists of 10 % of anhydrous ethanol and 90 % of gasoline, and E85 shows a blend of 85 % of ethanol and 15 % of gasoline. E10 is the most popular gasohol blend due to the fact that no modifications are required in

motor engine to run on E10. Generally blends below E10 are widely acceptable fuel and are used in many countries around the world leading USA and Brazil where ethyl alcohol represents 10-20% of gasoline supply. E5 to E25 are considered as low blend gasohol whereas E30- E85 are generally assumed as high ethanol blends. E85 is one of the most popular blend which is considered as alternative fuel, while lower blends are generally not assumed as alternative fuels. Ethanol blends are being used in the following countries e.g. E20 to E25 are used in Brazil, E5-E10 in Canada, E10 in China, E5 in India and E10 - United States. Nowadays, many car manufactures have been modified cars equipped to run on up to E20.

2.5) Advantages of Gasohol:

An an alternative clean fuel, gasohol encompasses several advantages over the widely used gasoline due to its unique blend with bioethanol. Some significant advantages of using gasohol are gasohol is more fuel efficient and cheaper than the regular gasoline. However, emissions due to gasohol burning are less toxic in compared to the gasoline only. Since, gasoline emissions are very harmful to the environment and its menifestations causes serious toxic effects and even can leads to human death. However, gasohol is cleaner as it emits less CO_2, and harmful chemicals like benzene, butadiene and SO_2 in compare to regular gasoline. Gasohol helps to keep vehicle engines cleaner by reducing buildup of burned residues in the internal system. In addition to this, the environment get benefitted with reduced CO_2 and SO_2 release. Since gasohol has highr octane level, as a consequence performance of gasohol has higher than regular gasoline in the same octane level. Gasohol also reduces the engine “knocking” so that vehicle runs more smoothly. Gasohol can be produced locally and thus reduces need for oil. Moreover, local production of ethanol creates large economic growth in energy and largely in agricultural sectors and related industries. Since, petrol blended with ethanol has up to 50% less emission of toxic benzene and butadiene compounds, both of which are carcinogenic substances. Ethanol also have the oxygenation properties that helps in the steady combustion of petrol. Moreover, gasohol is economicallty cheaper than the petrol as gasohol is cheaper to synthesyzed. Blending of ethanol to gasoline enhances the octane level of the mixer that leads to highr performance. Higher octane fuels also burn more slowly, reducing engine "knocking", and leading to smoother running. Gasohol production is cheaper since ethanol is about 40% cheaper to manufacture than extraction of petrol hence by using more ethanol the price of the vehicular fuels will reduce significantly. Gasohol helps in the reduction of oil imported from other countries. Hence, by minimizing the toxic pollutants emissions in atmosphere, we can ensure a greener environment, but also a healthier population.

2.6) Disadvantages of Gasohol

Since 1998, many automobile companies have been equipped to manufacture gasohol compatible vehicles. However, in contrary there are several disadvantages associated with fuel containing ethanol. Gasohol in which the ethanol is obtained from crop grains are expensive and energy intensive to produce, and can damage some integral parts of engine at higher ethanol concentrations. Hence, the compatibility of vehicles to different formulations od gasohol is a major concern. Methanol-based gasohol is also expensive to produce as well as toxic and corrosive, and emit cancer-causing chemicals like formaldehyde. The use of anhydrous ethanol in automobile engines can only be feasible if the internal engines are designed specifically for combustion of gasohol, and used only in the specifically designed light vehicles. Moreover, since ethyl alcohol for gasohol is made from certain crops such as sugarcane, sorghum e.t.c. Therefore, ethanol production will increase the demand and consequently the cost of these crops with the production of gasohol. Exhaust emissions from blends with higher ethanol contents may further worsen the health associated risks due to air pollution and may pose new safety risks. Also, higher blends may further compromise the self life and performance of the vehicles used. For example, gasohol may corrode the internal engines and provide supply low energy per unit volume than the dieseal and gasoline. Also a question remain ananswered that whether gasohol will reduce the GHG emissions when we will consider the full life-cycle impacts of this fuel. These enumerable serious questions are the focus of many of the ongoing studies that have yet to show a comprehensive dataset suitable for definitive scientific assessment of the gasohol blends beyound E10.

3.1) Will gasohol production compete with food and feed production?

Besides food grain crops, there are many other different sources of feedstocks are available for ethanol production such as food industries wastes, vegetable waste, spoiled crops, which cann't put burden on the agricultural land for crop production. It is westimated that ~1-2 billions gallons of ethanol every year could be produced without having any significant concern on food production and food prices. Moreover, ethanol may also be produced competitively from cellulosic residues having very little impact on crop production and prices.

3.2) What are the environmental impacts of gasohol production?

The selection of feedstock for ethanol production is one of the very crucial parameter in considering the impact of gasohol production on the environment. As requirements for production of ethanol increases beyond the available feedstock then the land requirements may be further needed for higher production to get more feedstocks. However, if grain crop is the major feedstock, then there would be a significant increase in the soil erosion and fertilizer as well as pesticides uses. Further, additional acres of land would be involved into cultivation of crops. However, the selection of diefferent feedstocks may alter these consequences. The impact of generated waste water from ethanol distilleries and their potential degradation can be minimized by some byproduct recovery or through the environmenta friendly waste disposal.

4) What are the economic and impacts?

The major economical and social impacts of ethanol bled fuel program are the potential for creation of new job opportunities for local farmers (in rural regions) and the chances of conflicts between the energy and food crops cultivation. Installation of more ethanol industries will lead to the harvesting process more mechanical that may lead to unemployment for local people and these people will only have the seasonal employments. There are some of the obvious advantages associated with the ethanol based fuel system implementation in any coutry. As the rate of production and the quality of ethanol required to be produced will be crucial factor in the social impacts. However, If bioethanol requirements increases beyond the available feedstocks then there would be a challenge to chose between the food crops and crops for energy production and the land requirements. Although farmers have supported gasohol initiatives in the expectations that the increase in production for feedstocks may lead to increase in prices, however, past experiences indicate that higher land prices may take a significant part of the income.

Challenges:

Sisnce the cost of ethanol production would be higher than the cost of fuels obtained from petroleum. A lot of plant material is needed to produce the ethanol, leaving lots of cellulose waste. Deforestation needed to make more useable land. Car engines need some special modifications to be able to use pure ethanol as fuel. Hence, a continuous progress in modern advanced ethanol production techniques would in near futureresult in higher ethanol production that would be competitive with petroleum fuels in cost of production and that will solve the ethical issue of using plants to produce fuel instead of feeding the hungry.

5.1) Reasons for adoption of ethanol-gasoline blends

Several countries along with India have supported the gasohol fuel as clean energy to reduce the burden of vehiculat GHGs emissions and also to decrease the import of fossil fuels. Therefore, it is considered that a morethan 5-10% of blending could result in substitution of millions of barrel of imported oil. The gasohol fuel is expected to contributr in lower emissions of CO_2, CO and toxic hydrocarbons.. In India, ethanol is primarily obtained from sugarcane molasses, a sugarcane refinery waste. In India, the blending of ethanol in petrol started in 2001. In 2003, Indian government mandated blending of 5% ethanol and later in 2006, mandated to use it throughout in India. In USA blending is allowed upto 10%. The clean fuel program of Brazil's began in 1976, where more than 94% of cars are having flexible fuel option that can use ethanol blends from 10-20%. Mass production

and applications of ethanol causes higher cost of food production due to the more land required and to maintain the energy and pollution balance for ethanol production, especially from corn.

5.2) Gasohol in India

Since 2003, India has started blending of ethanol in petrol to be used as automotive fuel. However, the actual scenario of ethanol blending with petrol yet to gather steam for wide acceptance. Further, a promosing inititaive has been taken to mandate the blend of 5% ethano (E5 blend). Already seven years have passed since the government launched the program to blend 5 % ethanol with petrol. However, the desired blending has not yet been achieved because of problems over pricing and procurement of bioethanol. However, oil marketing companies are purchasing million liters of ethanol from sugar mills, making this to reach the country will reach its E5 blending target. The gasohol program will reduce the country's billion dollars annual fuel import expenditure. However, if we go to 10 %, one could save foreign exchange currently being used to import crude. Since, in India, more than 80% of annual crude oil is imported to which the expenditure are around billions of rupess. It is expected to beneficial for farmers as well as to industries in future. In India, Government has recommended the use of E5 and Society for Indian Automobile Manufacturers (SIAM) has accepted for the use of E5 blend in vehicles. In this regard, In 2002, India has also signed a Memorandum of Understanding (MoU) with Brazil technology transfer in the fields of ethanol blending with petrol and diesel.

6.1) Case study of Gasohol in Brazil

6.2) Why Brazil is chosen for case study?

Worldwide Brazil is the first country who have successfully adopted the gasohol program using bioethanol produced from sugarcane-based feedstocks for it automobile fuel requirements. Currently Brazil has blending of bioethanol in the range of 25-30 %. However, in other countries such as USA, ethanol blending in gasoline is sloley due to environmental concerns. Since Brazil have favorable climates and tradition of sugarcane cultivation where ssugarcane being the most efficient available raw materials for bioethanol production. Gloabally, Brazil is considered as the second largest producer of bioethanol and was the first to made cheapest bioethanol. Brazil and the USA together contribute to the highest production of total industrial ethanol in world's. Currently Brazil is the being the highest produces and consumers of bioethanol now become the global leader in the use of gasohol as an alternative to the petroleum based fuels. Therefore, the success story of the Brazil's bioethanol sector could provide resourceful insight into the parameters that contribute to the success of the gasohol fuel. However, understanding the problems encountered by gasohol industry would be useful in determining how the future ethanol industry could be even more efficient and productive. Currently sugarcane is considered as one of the most efficient feedstocks for ethanol production e.g. 1 ton of bagasse produce 186 Lts of ethanol. Brazil's has a long history as in the early 1990s when the government of Brazil has directed the gasohol production and started compulsory blending of ethanol in gasoline. Following this alter on this proportion increased upto 40% in some regions of the country. Then after initial success, the government began to large scale support of the ethanol industry. Use of 5% alcohol in petrol was made compulsory in Brazil in 1931. Thereafter, blending of alcohol with petrol to be used as transport fuel started after the oil crises in 1973. In 1985, Brazil has launched a program of using gasohol mixture of 75 to 80% inferior grade gasoline and 20 or 25% ethanol, and thus saved 40 % of its petrol consumption.

The OPEC embargo of 1970s leads to economic crisis in several countries including Brazil, Since these were importing more than 80% of crude oil and the prices of crude oil were rising. Furthermore, the fall of sugar prices lead to sugar producers to look for other avenu to increase income for their survival. These two events led to the expansion of the ethanol industry. In response to the oil crisis, In 1975, Brazil launched the National Alcohol policy to increase ethanol production and to reduce its reliance on imported. The policy included: subsidizing the automobile industry to produce gasohol compatible engines, tax benefits for gasohol compatible vehicles, setting the ethanol price competitive

with gasoline and subsidizing distribution of the new fuel. As a result of these initiative, ethanol production increased many fold.

In 2003, car manufacturing companies in Brazil have introduced flexi vehicles or flexible-fuel vehicles that can take on various forms of gasohol and this was a commercial success with all light vehicles. Towards the end of 2010 many new models of flex vehicles were available in the market and as of 2013, many car manufacturers started to make flex-fuel compatible engines in the light vehicle segments. The commercial success of flexi vehicles, together with the essentiial blend allowed gasohol consumption achieve a significant market share of the gasohol consuming vehicles. Moreover, in view of energy equivalent, gasohol however, represented approx. 18% of the country's total energy usages by the transport sector. However, waste generation was a big issue e.g. Bagasse and Vinasse. Bagasse is leftover sugarcane fiber during ethanol extraction whereas vinasse is a toxic byproduct of bioethanol production. These waste products are generally dumped in water bodies that lead to water pollutions. However, alternative solutions have been found for sustainable usages of the same. E.g. Vinasse could be a good fertilizer for agricultural purposes. The Brazilian government sets mandatory minimum blending rates for gasohol. For the past 25 years these have typically varied between 20% and 25%, providing a secure market for the equivalent of over 10 million tonnes of sugar each year.

Summary

Gasohol fuels are developed as an alternative clean fuels for moto vehicles since it is often associated with a concept of “green” energy that contribute to reduction of GHGs. Gasohol is advantageous in reducing the country dependence on fossil fuels and it controls the CO_2 emissions significantly. It is comparable in performance to 100 % unleaded gasoline with the added benefit of superior anti-knock properties. Globally there is a growing interest for gasohol production due to the continuous depletion of fossil fuels and for the environmental safety. Brazil is considered to adopt the world's first sustainable clean energy economy. When fully implemented the program can confer tangible benefits on the economy of the country on the energy front. Taken together, gasohol has higher octane, or antiknock, properties than gasoline alone and combustion is more slowly, and completely, resulting in less emissions of pollutants.