BIOETHANOL: A SUSTAINABLE AND ENVIRONMENT FRIENDLY SOLUTION FOR PAKISTAN

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ABSTRACT

Ethanol has the potential to reduce total dependence on fossil fuels for energy needs and mitigate environmental pollution. Presently, it is substituting approximately 3 % of the fossil-based gasoline consumed world over. In Pakistan, bioethanol is produced through fermentation of sugarcane molasses. Petrol consumption in Pakistan is approximately 1.6 million tons, and 10 % blending of ethanol can give rise to 160,000 tons of fuel ethanol consumption. Pakistan has the capacity to produce this quantity of ethanol from sugarcane molasses. By implementing an ethanol blending programme, the environmental benefits, particularly reduced emission of greenhouse gases, can be achieved. This will also help to meet the future energy needs as well as save the national exchequer.

1. INTRODUCTION

Lately, there has been a universal consensus that global warming is predominantly due to greenhouse gases (GHG), including nitrous oxide (N_2O) and, especially, carbon dioxide (CO_2) and methane (CH_4). This distress forced many nations to reach agreement on Kyoto Protocol (1997). Pakistan ratified the Kyoto Protocol on Climate Change in 2004 and weighted the scientific innovation's potential as a way to tackle GHG emissions (Daily Times, 2004). Kyoto targets have not been met so far. The reality is that the situation is likely to become more complicated in the next few years.

About 27 % of primary energy worldwide is used for transportation (EIA, 2006). Approximately 28 % of the energy in the EU25 countries is consumed by transportation, of which, more than 80 % is for road transport (Eurostat, 2007). Transportation fuels are thus promising targets for reduction in GHG emissions. Existing requirement of oil is about 12 million tons a day (Qin, et al., 2007) with a projection to increase to 16 million tons per day by 2030. While 30 % of the global oil consumption accounts for transport; a striking 60 % of the rising demand is expected till 2030.

The share of petroleum products is about 40 per cent in the current energy-mix in Pakistan. Its consumption has grown sharply, dominated by gasoline and fuel oil. Gasoline is mainly consumed by transport sector by public and private sectors (Business Recorder, 2011).

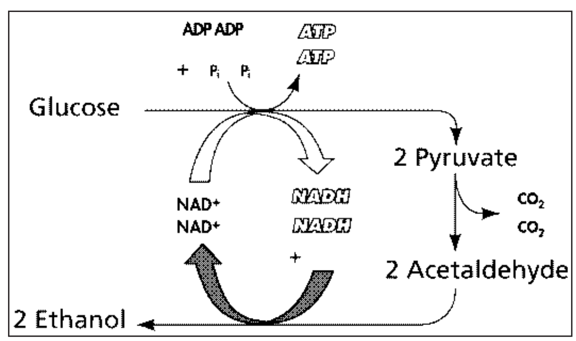
The availability of conventional oil is geographically restricted and a general agreement now is that the era of cheap and secure oil (cheap energy) is over.

In an attempt to replace natural gas and oil in the transport sector, numerous substitutes are currently being explored (photovoltaics, wind and nuclear power). However, there is bioethanol that emerged as a real alternative to the use of gasoline and conventional diesel used in transportation. An exponential increase in consumption of such biofuels has taken place in the last few years.

2. PROCESS FOR BIOETHANOL PRODUCTION

Saccharomyces cerevisiae is the principal organism for bioethanol production, capable of metabolizing glucose, fructose, mannose, galactose, sucrose, maltose, and maltotriose. Embden-Myerhof-Parnas (EMP) pathway (Figure-1) is utilized for ethanol production by *S. cerevisiae.*

In the simplest form, ethanol formation from glucose can be shown as following:



The theoretical yield is 0.511 g ethanol produced per gram glucose consumed. Practically, this yield can never be attained because not all of the glucose consumed is converted to ethanol but part of it is used for cell mass synthesis, cell maintenance, and production of by-products, such as glycerol, acetic acid, lactic acid, and succinic acid. However, at industrial scale, it remains 90 to 95 per cent of the theoretical yield under ideal conditions.

3. SUBSTRATE

Molasses, a byproduct remainant after the formation of raw-cane sugar from sugarcane juice (Hugot and Jenkins, 1986) containing some high value

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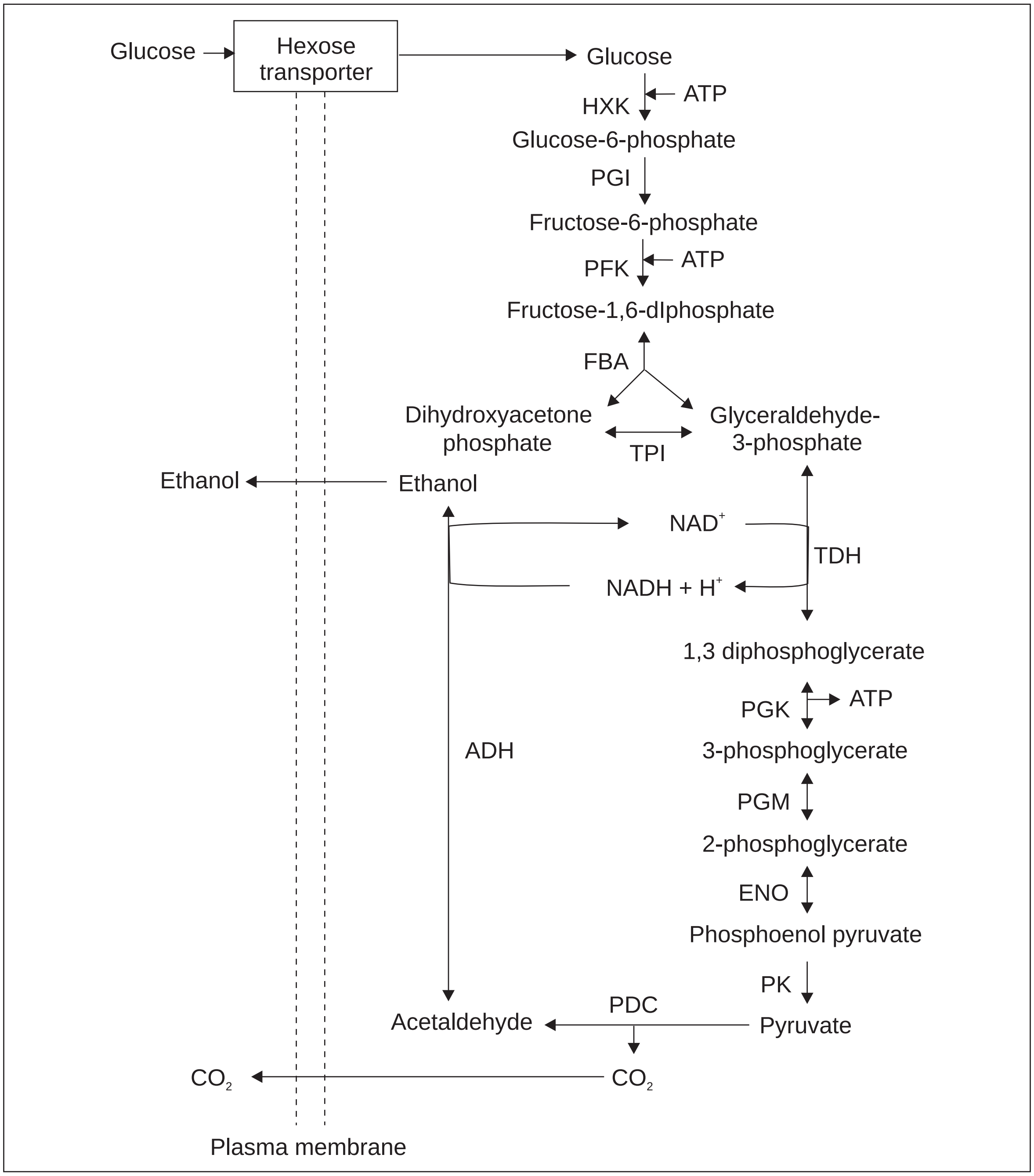

Figure-1: The Glycolytic Pathway for Ethanol Production in *S. cerevisiae*
Note: *(HXK: hexokinase; PGI: phosphoglucose insomerase; PFK: phosphofructokinase; FBA: fructose bisphosphate aldolase; TDI: triose phosphate isomerase; TD: triose phosphate dehydrogenase; PGK: 3-phosphoglycerate kinase; PGM: phosphoglycerate mutase; ENO: enolase; PK: pyruvate kinase; PDC: pyruvate decarboxylase; ADH: alcohol dehydrogenase)*

disaccharides and monosaccharides with minerals that are regarded as impurities in raw sugar. The fermentable sugar content of molasses varies inversely with the purity of the raw sugar produced at the factory. Molasses is a low value product that is used as cattle feed supplement, in specialized yeast propagation or as a flavoring agent in some foods (Troiani, 2008).

4. POSSIBLE BENEFITS FROM THE USE OF BIOETHANOL IN PAKISTAN

4.1 Reduced Emissions

Ethanol contains oxygen while the amount of carbon monoxide (CO) and unburnt hydrocarbons in the exhaust is reduced considerably. With introduction of ethanol in fuel-mix for transportation in Brazil, CO emission from automobiles decreased from 50 g/km in 1980 to 5.8 g/km in 1995 (Goldemberg, 2008).

One of the disadvantages in using pure ethanol is that aldehyde emissions are higher than those of gasoline, but it must be observed that these aldehyde emissions are predominantly acetaldehydes. Acetaldehydes emissions generate less adverse health effects when compared to formaldehydes emitted from gasoline engines.

4.2 Reduction in Greenhouse Gas Emissions

The net CO_2 emission of burning a biofuel, like ethanol, is zero since the CO_2 emitted on combustion is equal to that absorbed from the atmosphere by photosynthesis during the growth of the plant (sugarcane) used to manufacture ethanol. This is illustrated by the following equations:

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6$ (plant sugar) $+ 6O_2$ (photosynthesis)

$C_6H_{12}O_6 + 3H_2O \rightarrow 3C_2H_5OH$ (ethanol) $+ 3O_2$ (hydrolysis and fermentation) of glucose

$3C_2H_5OH + 9O_2 \rightarrow 6CO_2 + 9H_2O$ (combustion of ethanol)

Life cycle analysis from well to wheels shows that ethanol has the lowest CO_2 emission among the major transportation fuels. Ethanol can thus contribute significantly to climate change mitigation by reducing CO_2 emissions.

4.3 Increased Employment

The bioethanol sector has the potential to serve as a source of substantial employment opportunities. A programme that generates employment is always particularly welcome in countries like Pakistan. The investment in ethanol industry in terms of job creation is significantly less than the job in the petroleum field. In Pakistan, the sugar industry, which is the backbone of ethanol production, is the biggest agro-industry. The sugar industry is the source of the livelihood of farmers and their dependants, comprising 70 per cent of the population. A few others are employed as skilled or semi-skilled labourers in sugarcane cultivation. Distilleries are the source of additional employment (Arshad, 2009). Direct employment in a distillery unit is approximately 60 persons. Persons having different backgrounds like biochemistry, microbiology and chemical engineering are required for the operation. Undoubtedly, Pakistan is an agricultural country due to which it has an immense potential to produce ethanol as a fuel. The existing production capacity of fuel-grade ethanol in the country is 270,000 tonnes per annum, which can be easily increased to 400,000 tonnes per annum with the increase in jobs. However, the bulk of raw molasses is exported, and only minor quantities are converted into industrial alcohol for domestic use and exports. This results in the loss of foreign exchange and employment opportunities.

4.4 Energy Security and Decreased Dependence on Oil Imports

Pakistan's energy demand is expected to grow exponentially each year. Pakistan's domestic production of crude oil currently satisfies only about 25 per cent of the country's consumption. Dependence on imported fuels leaves Pakistan's economy vulnerable to possible disruptions in supplies, which may result in physical hardships and economic burdens. The volatility of oil prices poses great risks for the world's economic and political stability, with unusually dramatic effects on energy-importing developing nations. Renewable energy, including biofuels, can help diversify energy supply and increase energy security, offering a favourable trade balance with saving of foreign exchange.

4.5 Good Fuel Properties

Due to high heat of vaporization, high octane number/rating and low flame temperatures, ethanol becomes an excellent fuel for transportation. Ethanol has an octane number of 120, much higher than that of petrol which is approximately 108.6. Thus, ethanol blending increases the octane number without having to add a carcinogenic substance like benzene or a health-risk posing chemical like methyl tertiary butyl ether (MTBE). The energy content of ethanol is only

26.9 MJ/kg compared to 44.0 MJ/kg for petrol. This would suggest that the fuel economy (km/litre) of a petrol-powered engine would be 38.9 per cent higher than that of an ethanol-powered engine. In actuality, this difference is 30 per cent since ethanol engines can run more efficiently (at a higher compression ratio) because of the higher octane rating. For a 10 per cent ethanol blend, the fuel economy advantage of a petrol engine is only 3 per cent. The flammability limit of ethanol (19 per cent in air) is higher than that of petrol (7.6 per cent), and similarly the auto-ignition temperature of ethanol is higher than that of petrol (363^o vs. 280^o). Thus, ethanol is safer than petrol due to the lower likelihood of catching fire. Further advantages of ethanol usage is that it:

- requires no change in existing engines (E-10);
- yields good engine performance;
- burns clean and more efficiently;
- is more biodegradable; as well as
- consistent with the global focus on biofuel.

List of some of the countries that are implementing biofuel programmes is given in Table-1.

5. ETHANOL INDUSTRY IN PAKISTAN

Molasses fermentation is done for ethanol production in Pakistan. The yield of sugar on average is approximately 85-95 kg per ton of cane. About 40 kg of molasses is produced per ton of cane from which about 10 litres of ethanol can be obtained. If the sugarcane is directly and fully used in ethanol manufacture, the yield of ethanol is 70 litres per ton. Currently, 21 distilleries produce industrial alcohol in the country. As many as eight distilleries have so far installed the molecular sieve technology to process industrial ethanol into fuel ethanol. Most of these distilleries are a part of sugar mills and are situated on-site, making the production cycle an integrated one.

6. ECONOMICS/COST OF ETHANOL PRODUCTION

By exporting molasses, only US$100 million can be earned, while by using raw molasses to produce blended ethanol fuel, Pakistan can save precious foreign exchange of about $600 million (Sibtain, 2009). Assuming an ethanol yield of 250 litres/ton of molasses, the raw material cost of ethanol is Rs. 9000/250 = Rs. 36/litre ($0.40/litre). After adding salary and wages of operational staff, capital related charges of investment, energy cost of producing anhydrous alcohol, the cost of transport and marketing, the cost of producing ethanol directly from sugarcane molasses is Rs. 45/litre ($0.53/litre). This compares favorably with the current world price of petrol. By using the spent wash more efficiently, ethanol price can be brought down further. Produced in large quantity (about 15 litres per litre of ethanol produced), can be subjected to anaerobic digestion that not only removes its BOD and COD but also

Table-1: List of Some of the Countries Implementing Biofuel Programmes

Country	Blending	Since	Country	Blending	Since
Brazil	E 24-26	1970	Costa Rica	E –07	2008
Thailand	E-10 E-20	2000 2008	EU	E-02 E-10	2003 2005
China	E-10	2004	Ireland	E-05	2007
Japan	E-03	2007	Bulgaria	E-05	2008
Australia	E-02	2002	Philippines	E-05	200
India	E-05 E-10	2003 2008	Colombia	E-05 E-10	2003 2008
Taiwan	E-03	2007	USA	E-10	2004
Netherland	E-02	2006	Canada	E-7.5	2005
Sweden	E-05		Pakistan	E-10	2006 & 2009

Source: *Antoni, D., Zverlov, V.V., and Schwarz, W.H., 2007.*

provides valuable biogas (60 per cent methane). This biogas can be used to offset 67 per cent of the energy cost of making anhydrous alcohol through distillation.

7. GASOLINE VS. ETHANOL

Ethanol is an oxygenate fuel, which means it has a more complete combustion than gasoline. Also, ethanol is a much slower burning fuel; it has an octane rating of 110, whereas regular unleaded gasoline has a rating of 87. The production and distribution of one cubic meter of ethanol results in emissions of 457 kg of CO_2 equivalent, which is very less as compared to gasoline (Oliveira, 2008).

8. A WAY FORWARD FOR PAKISTAN

Pakistan State Oil (PSO) has launched E-10 gasoline pilot project at designated retail outlets in Karachi, Lahore and Islamabad. It is based on a detailed feasibility study conducted by the Hydrocarbon Development Institute of Pakistan (HDIP). The new fuel —10 % ethanol blended with motor gasoline — is being introduced experimentally as part of government's strategy to promote alternative energy resources. The pilot project was conducted for 6 months, with 25 pre-identified vehicles using ethanol-blended gasoline in each city. The monitoring of these vehicles was carried out by HDIP. Based on the results of the project, the blended fuel would be made available throughout the country. Pakistan's sugar industry has a capacity of producing four billion liters of ethanol annually (Umar, Nasir and Tariq, 2008)

In July 2006, PSO took the initiative to launch the pilot project of ethanol filling station in Pakistan. Although PSO in collaboration with Hydrocarbon Development Institute of Pakistan (HDIP), initiated a pilot project to introduce ethanol fuel blended with gasoline in a 1:9 ratio (E10) at three petrol pumps in Karachi, Lahore and Islamabad, this venture failed due to lack of coordination among various stakeholders, and gaps at planning and implementation stages.

The Economic Coordination Committee (ECC) of the Federal Cabinet of Pakistan has decided to allow marketing of Ethanol-10 as motor vehicle fuel on trial basis at PSO stations.

The ECC met under the chairmanship of Shaukat Tareen, Adviser to PM on Finance and Economic Affairs at the Prime Minister's Secretariat. The decision to allow marketing of E-10 was taken to reduce reliance on imported petroleum products, to the extent possible through use of appropriate indigenous blendable substitutes. Anhydrous Ethanol (Ethanol with less than 1 % water) is one such product, which can be blended with gasoline in varying proportions. Most gasoline vehicle engines operate well with mixtures having 10 percent Ethanol E-10. The ECC further decided that Ethanol-10 would be treated as motor vehicle fuel (Sajid, 2010).

Government of Pakistan imposed a 15 % duty on molasses export to favour the use of molasses for ethanol production rather than export. Achievement of cheap and renewable energy has become an important issue in energy management and economic development in all the countries.

If all molasses produced is converted to ethanol, it can replace 5-7 % of gasoline. It will be a significant contribution to the overloaded economy. Pakistani government should formulate policy to implement the initiative of blending ethanol in transportation fuels as soon as possible.

REFERENCES

- Arshad, M., 2009. Employment Generation through Bio-ethanol Production Industry as Renewable Energy. In: COMSATS, Policies and Strategies for Successful Implementation of Employment Generating Programmes in Renewable Energies, Biotechnology, Agriculture, Environment and ICTs, Islamabad, Pakistan, August 11-12, 2009: Islamabad.
- Antoni, D., Zverlov, V.V., and Schwarz, W.H., 2007. Biofuels from microbes, Appl Microbiol Biotechnol., 77(1), pp. 23-35.
- Business Recorder, 2011. Petroleum: BOSICOR Pakistan Limited - Analysis of Financial Statements - Financial Year 2004 - 3Q Financial Year 2011. Available at: < http://www.brecorder.com/company-news/single/601/0/1206856/?date=2011-06-29>.
- Daily Times, 2004. Pakistan ratifies Kyoto Protocol. Available at: <http://www.dailytimes.com.pk/default.asp?page=story_17-12-2004_pg7_7>..
- EIA, 2006. Office of Integrated Analysis and Forecasting. *International Energy Outlook*, DOE/EIA- 0484 2006: US Department of Energy,

Washington, USA.

- Eurostat, 2007. Online Database of the European Union. Available at: <http://epp.eurostat.ec.europa.eu,> Eurostat. Accessed on 08.05.2007.
- Goldemberg, J., 2008. The Brazilian biofuels industry. *Biotechnology for Biofuels*. Available at: <www.biotechnology forbiofuels.com>
- Hugot, E., and Jenkins, G. H., 1986. Handbook of Cane Sugar Engineering. Amsterdam: Elsevier,
- Qin, D., (eds.) et al., 2007. Changes in Atmospheric Constituents and in Radiative Forcing, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, USA, p.996.
- Oliveira, M.D. De, 2008. Sugarcane and Ethanol Production and Carbon dioxide Balances. In: Pimentel, D., (Ed.), Biofuels, Solar and Wind as Renewable Energy Systems: *Springer Science*. Cambridge University Press, Cambridge, United Kingdom and New York, USA.
- Sajid, C., 2010. Use of Bagasse with Coal as Fuel: Sugar Industry Allowed to Co-generate Power in Lean Season. *Daily Times,* April 06, 2010.
- Sibtain, R.K., 2009. An Eco Friendly Resource. *The News,* Sunday, 25 Jan., 2009.
- Troiani, E., 2008. Sugarcane Factory Types (Personal Communication, A. R. Gopal, Jakarta, Indonesia).
- Umar, K. M., Nasir, A., Tariq, M., 2008. An Overview of Biomass Energy Utilization in Pakistan. *Renewable and Sustainable Energy Reviews*, 12, pp. 1988–1996.