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# Biofuels India

Conserving resources, protecting the environment

Sustainable Fuel for the Energy and Transport Sector

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*Panel Discussion at the 6th International Biofuels Conference*

## EDITORIAL

# Of Cabbages and Kings…

by Sudhir Singhal, Senior Advisor (Energy and Environment), WII

What is the future of transportation? What is going to be the source of motive power – one that will be sustainable and give rise to no pollution? The answer to these questions, as we see it today, is easy – electric power. But when would it happen? No precise answers to this one, but it is agreed by one and all that the day is not far away provided we work towards this. The technological issues are clear and simple. Briefly, storage battery technology and environmentally friendly power production which basically will come from the Sun. It is widely understood that 1% of the incident solar energy on earth is more than sufficient to meet the entire energy needs of the planet. Yes, to achieve this we have to factor it in our global, national and R&D planning. Cooperation will go far on this one and one can then achieve early breakthroughs. Yes, our goals of no GHG problems, no global warming and consequent melting of ice caps and rise of sea levels, and many others would be met. The atmospheric $CO_2$ level rise could then slow down, be arrested, and begin to come down from the current value of 385 ppm.

Till this happens, different nations and societies will follow their own pathways depending upon resource availability and technology preparedness. It is these different options that are generating so much "heat" today. The current panacea appears to be biofuels which achieve substantial and significant $CO_2$ sequestration compared to business as usual. Bio-ethanol, particularly from surplus and waste biomass, and bio-diesel from algal sources, are the emerging technological options. Shortly thereafter, bio-hydrogen is also expected to join this select group. All biofuel routes are finally linked to the sun as the primary source of energy. For these options to be feasible and come into play, policy initiatives, regulatory mechanisms, and above all, sufficient R&D support would be necessary. The conflicts with the existing and so far established industry and infrastructure will also have to be addressed. Yes, there would be short term pain in this transition but this would have to be borne. Also, all nations will need to find their own individual direction. Though very attractive and perhaps necessary in the short and the medium term, this (biofuels) also will ultimately have to give way to solar derived electric energy.

The internal combustion engine and gas turbine, the established power

*Contd. on Page 12...*

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# The 6th International Biofuels Conference: A Report

**by Sudhir Singhal, Sr. Advisor, Winrock International India**

Winrock International India, each year since 2003, has been taking the initiative to provide a neutral platform to stakeholders from across the world to share their experiences, discuss and debate relevant issues, which could help formulate effective policies for the promotion of biofuels in the country.

The sixth in the series of International Biofuels Conferences was organized on March 4 and 5 at its now established venue, Hotel Le Meridien, New Delhi. The 6th International Biofuels Conference, under the theme **Biofuels in India - Setting New Paradigms,** was held in its usual impeccable style. Spread over seven sessions, more than thirty five papers were presented at the conference covering issues on: Policy perspective on biofuels; Biofuels and transport sector; Food v/s fuels debate; Voices from the States; Next Generation Biofuels; Sustainability issues; Biofuels being the driver for rural development and Future Directions: A Panel Discussion.

The conference was inaugurated by **Mr. Debashish Majumdar, Chairman and Managing Director, Indian Renewable Energy Development Agency Limited**. In his address he mentioned that of the 145,000 MW installed capacity in India, 9% is from renewables. He said that the moment we talk of biofuels we really have to coordinate the activities of all the ministries to make progress in one direction. A major policy change would be required for this, and one that will encourage investments in the entire biofuels chain, at various levels like cultivation, production, transportation, and for long term investments by the private sector. This should be taken up as soon as possible. In the context of biofuels, he concluded by saying, "If we love our children then let us do something good to make sure that we leave a good and healthy place for our children".

Welcoming the delegates, **Mrs. Pushpa Sundar, Chairperson, Winrock International India (WII)**, started the conference proceedings and mentioned that the conference had tracked the progress made in


*Mr. Debashish Majumdar, Chairman and Managing Director, Indian Renewable Energy Development Agency Limited inaugurating the 6th International Biofuels Conference. Also present on the occasion are (left to right): Mr. Anand Kumar, Director, Research & Development, Indian Oil Corporation Ltd.,Mrs. Pushpa Sundar, Chairperson, WII and Dr. Kinsuk Mitra, President, WII*

*Participants at the 6th International Biofuels Conference*

the scientific development and application of biofuels in India over the years, and has been a major landmark in India's development calendar. She said that WII has been engaged in in-depth research and analysis and production of biofuels and has also successfully demonstrated the use of straight Jatropha oil for electrifying a village in Chhattisgarh. She stressed that Winrock India remains committed to the biofuels agenda and will continue to promote its growth in a way that is tailor made for the Indian situation.

**Mr. Anand Kumar, Director, Research & Development, Indian Oil Corporation Ltd.,** delivered the special address. He highlighted the fact that carbon dioxide levels have reached 385 ppm and with business as usual, will lead up to 500 ppm, and since the population has to survive, economic growth has to take place for which energy is required. This, he said, brings out the importance of biofuels. He brought out the relevance of the subject for India, briefly mentioning the initiatives IOCL has taken in this direction, particularly for the second generation of biofuels. He mentioned the IOCL initiatives for production of biojet fuels, initiation of research on algal biodiesel, joining hands with NREL, establishing a Centre of Excellence in Biotechnology, setting up of a lignocelluloses pilot plant for ethanol and many others. He said that we should increase our share of biofuels with the sole objective of reducing the $CO_2$ emissions much ahead of our target of 2020. He also said that the Indian oil sector is working to reduce the impact of $CO_2$ emissions from each and every one of our activities. He complimented Winrock for playing a very important role in assembling the people and sharing information through this conference.

**Dr. Kinsuk Mitra, President, WII,** spoke of the fascinating story of biofuels, stating that the first conference on biofuels, organized by WII, had very few answers to provide and in this, the sixth one we realize that biofuels have the potential to address two major and equally important national priorities - one, to lower our import dependence on fossil fuels; two – equally importantly, to use biofuels as a driver for rural development. He recalled the launching of the Ranidehra initiative last year and mentioned that it has operated every single day for the last 21 months. He stressed that we need a strong biofuels policy, which could drive us in the right direction to take India forward, as it could change the way we live on this planet.

There were about 350 delegates who attended the conference, representing virtually all sectors relevant to the progress and development of biofuels. About 40 delegates were from outside India, representing countries such as Germany, Switzerland, Japan and

Netherlands, among others. A key highlight of the conference was the enormous student participation from a number of engineering and technology universities from all across India.

The thoughts expressed at the conference covered several significant aspects of biofuels' progress and spread, as well as the cautions and concerns that need to be taken care of. These can briefly be summarized as follows:

- Self sufficiency in energy requirements is critical to the success of any growing economy. Investing in R&D for biomass energy is investing in our farmers, environment and economy, that is, in our future.
- Biomass represents an abundant carbon neutral renewable resource for the production of bio-energy and for bio-materials.
- Advances in genetics, biotechnology, process chemistry and engineering are leading to new manufacturing concepts for converting biomass to valuable fuels and products.
- The integration of agro-energy crops and bio-refinery manufacturing technologies offers the potential for development of sustainable bio-power and bio-materials that will lead to a new manufacturing paradigm.
- The potential benefits of biofuels have been assessed but priorities have to be identified and technologies researched upon.
- The CDM under the Kyoto Protocol, has the dual goal of reducing GHG emissions and promoting sustainable development. However, no biofuel projects are among the 1300 approved projects in the current CDM portfolio; lack of available approved baseline and monitoring methodologies need to be quickly relooked at and finalized.
- LCA is a useful tool for the consideration of environmental aspects of sustainability. The development of a data model that takes all relevant issues into account is important as it is not feasible for every producer of biofuels to commission a full-scale LCA study.
- Biodiesel is an accepted, environmentally and technically feasible alternative for India. A roadmap for its sustained availability should be quickly prepared, in consultation with all stakeholders working together; that will make life better for all of us. Considerable employment opportunities can arise through this.
- The biodiesel industry can be significantly more attractive if the by-product streams are exploited for value addition. The seedcake, through catalytic and enzymatic conversions, and extractions, is a prime example. Bio-lubricants have also been prepared. Considerable research is in progress worldwide and in many cases available for commercial exploitation.

*Participants interact with speakers at the conference*

- Large scale examples of Jatropha plantation are now evident. These have been encouraged in waste and degraded lands as a policy. Bio-diesel and SVO-based remote village electrification and irrigation projects appear to be entirely feasible for Indian villages, and by implication, in some other areas of the world as well.
- The advent of second generation biofuels and beyond, e.g., ligno-cellulosic bio-mass appears to be playing a growing role and is expected to reach 2% of total liquid fuel supplies by 2030. After this, it is expected to grow at an even faster rate. Pre-treatment of cellulose has a major influence on the cost of prior and subsequent operations (enzymatic hydrolysis and fermentation). The R&D challenge is to optimize these and bring down the cost of cellulases. Co-processing of lignin is important and has commercial implications.
- Breeding high yielding and high oil containing cultivars of Jatropha and Pongamia is a must, to harness their full potential since molecular techniques have revealed variability in the germplasms. Thus science–led development is necessary to harness their full potential. Quality planting material meeting local agronomic requirements should be of priority.
- Jatropha cultivation can help halt soil erosion, increase water storage in soil and transform barren expanse into productive land.
- New process developments to achieve high yields of biodiesel, without the need to neutralize and wash the biodiesel are now available. This is attractive where conservation of water resources is critical.
- Algae are predicted to be a major renewable resource for biodiesel. Research on triacyl-glycerol

producing algae, the molecule which is a preferred precursor, appears to be making good headway. These could be commercially available in the very near future.

- Sweet sorghum appears to be a "smart crop" for ethanol production. Addressing some core issues can put this in the forefront of biofuel production. Region specific research activities and developing cultivars through conventional breeding methods and through modern molecular tools, which has begun, would be very useful.
- Production of bio-hydrogen, including from biomass, could provide a significant portion of energy demand in the future. Today, each of the conversion routes identified have their advantages and challenges. Genetic engineering tools can address these challenges. Dark fermentation and biomass gasification using bio-catalytic and microbial route for water gas shift reactions seem to be attractive.
- Policy makers face a dilemma over the production of biodiesel to its high social costs. An analysis of the problem from a social, individual and environmental point of view shows that benefits score far more than costs, in the long run. A sustained long term policy would therefore be of considerable benefit.

The last conference session, **FUTURE DIRECTIONS,** was a lively panel discussion in which the panelists were an eminent cross-section of stakeholders in the area of biofuels.

The delegates also contributed significantly towards the discussion. The issues deliberated in this session included:

- The Need for Policy
- The Food v/s Fuel issues
- Research Requirements
- Achieving Coordination between Stakeholders
- Economic Models
- The Short, Medium and Long Term Priorities for Different Fuel Alternatives

The views expressed at the panel discussion brought out that the way forward for India, to benefit from the knowledge base that has already been created, is to:

- Appreciate that India has different kinds of geo-climatic conditions – and – therefore region specific programs would be required. To achieve this, we must look at multiple feedstocks and their sustainability. Also, in each of the species the right geno-types and quality planting materials would be necessary.
- Carry out systematic science based research in a manner that results reach the masses and the stakeholders. A centre-point for information and its dissemination would be crucial for success.
- The protocols for plantation which are already developed, should be quickly validated. In this context it was felt that we perhaps have enough land for both food and fuel but we have to identify and exercise our options correctly.
- We have to inventorize all the options that are possible for utilization of biofuels, analyze their pros and cons for a given time frame, and, ensure that minimum side-effects and infrastructure requirements arise. As an example, could the small amounts of bio-diesel that we may have in the early years, preferentially go for standby diesel generating sets? This would ensure full utilization of all available material but not expose the vast automotive population to variable fuel quality and specifications. Similarly, can we develop appropriate cook-stoves for bio-diesel so that the villages can directly benefit and we do not have to transport it far and wide? This may prevent kerosene diversion and adulteration as well.
- For automotive applications, any program for mandating blends should be uniform for the whole country, and more importantly, be sustained over a period of time. A switch-on and switch-off mode could lead to inefficiencies and other problems in today's and tomorrow's high-tech automotive designs.
- The policy for biodiesel should not be dependent on the crude price, should be people-centric and must look at the village as a focus point. Apparently, the economics of the local consumption model are highly favorable and should be sustained for the long term.
- The huge amount of waste biomass available in and around the villages, and, in the forests, should be efficiently used. This may help lower the huge national energy bills.

## 7th International Biofuels Conference

Preparations have commenced for the next conference. WII shall soon announce the dates for the conference to be held in 2010. Meanwhile, interested authors are encouraged to get in touch with us.

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# Value Added Products from By-Products of Karanja Oil-Based Biodiesel Industry

by Dr. R.B.N. Prasad, Head, Centre for Lipid Research, Indian Institute of Chemical Technology

## Introduction

The two most important plantations chosen by various Indian state governments as well as the central government for the preparation of biodiesel are Jatropha (*Jatropha curcas*) and Karanja (*Pongamia pinnata*). Huge plantations of both the crops are being initiated by the farmers throughout the country. Technology providers are making themselves ready for the process of making biodiesel from these oils. However, at the present moment the big question mark lies on the economics of the biodiesel industry. As the oil cost is a little high and some pre-processing is required, the production cost becomes very high and it loses to diesel, at least for the time being. The need of the hour, therefore, is to have a proper technology to handle multi-feed stock and, more importantly, the by-product utilization. Effective utilization of by-products like deoiled-cake, glycerol, phytochemicals and fine chemicals would certainly help the economics of biodiesel. To make the biodiesel production economically viable, R&D efforts are needed for the production of other value added products from various parts of the plant like leaf, flower, bark and cake. This in turn, will motivate the farmer going for the plantation of these crops. The main purpose of this lecture is to present the potential applications of karanja oilseed cake, oil and glycerol.

## Bioactive Constituents from Karanja Cake

The extensive use of Karanja plant in Ayurveda makes the researchers around the world look at this plant more closely and also examine different parts of this plant, like stem, bark, seed, flower and leaf. The published literature on karanja tree reveals that its seeds and oil have a lot of potential for bio-pesticides and other important chemicals. Several minor constituents like karanjin, pongamol, pongapin, kanjone, pongaglabrone, isolonchocarpin, pongachalkone glabone, pongacoumestan and karanjchromene were isolated from the karanja seed and oil. Most of these compounds distribute both in oil and expelled cake and only polar solvents can extract these components completely. Sporadic efforts were reported in the literature for their use in pesticide, insecticide etc. Literature reports indicated that these minor constituents exhibit several activities like pixidal activity, nematicidal activity, antitubercular activity and the insecticidal activity. Ethanol extracts of karanja seed coat were reported to have mosquito repellant activity. However, systematic studies were not reported for the exploitation of these minor constituents. Even though thorough studies on some of these components are available, detailed studies are required for commercial exploitation of these bioactive constituents.

Biodiesel plant produces about 2 tonnes of karanja cake for every ton of biodiesel produced. Any oilseed cake is a real asset for the nation as it is biodegradable. Presently both Jatropha and Karanja seed oils are extracted using the expelling process. The resulting cake contains about 8 to 14% of oil depending on the efficiency of the expeller. In some cases, expelled cake is further extracted with solvents to remove the residual from the cake. As both Jatropha and Karanja cakes have not yet been exploited, very limited information is available on the composition of these deoiled cakes. This biodegradable waste, if handled properly, would maintain the natural balance of essential elements and thereby promote more harvests from nature. The composition of karanja de-oiled cake is provided here in Table 1.

As the Karanja cake is reported to be rich in several bioactive constituents, IICT has developed

**Table 1: Composition of Karanja Oilseed Cake**

| Constituent | Karanja |
|---|---|
| Nitrogen/Protein (wt %) | 4-7/25-40 |
| Carbohydrate (wt %) | 15-20 |
| Fibre (wt %) | 15-20 |
| Ash (wt %) | 3-5 |
| Phosphorus (wt %) | 1-2 |
| Potassium (wt %) | 0.5-1.5 |
| Calcium (wt %) | <1 |
| Magnesium (wt %) | <0.5 |
| Zinc, Copper, Magnesium, Boron (ppm) | <100 |
| Sulphur (ppm) | <4000 |

methodologies for the isolation of bioactive constituents and bio-evaluation of the major furano flavonoid, karanjin. An efficient method was developed at bench scale for the extraction of karanjin from karanja deoiled cake. The process involves extraction, using polar organic solvent, to get the bioactive constituent-rich crude extract containing 15-25% of karanjin. The crude extract, on further crystallization, yields karanjin of purity in the range of 90-98%. The extraction process does not require any column chromatographic purification at any stage. About 3.0-4.5 g of karanjin-rich extract containing 90-98% of karanjin was obtained from 1.0 Kg of deoiled cake using this process. Bio-evaluation of crude extract was carried out, especially the mosquito larvicidal activity and excellent result was obtained. The activity of the extract was studied on *Aedes aegypti* and *Culex* mosquito strains and excellent mortality was observed at a very low concentration [LC50 (Mean ± SE) was found to be 10.4 ± 1.17 in case of *Aedes aegypti* strain and 2.29 ± 3.45 ppm *culex* strain]. Further, studies are in progress to find the possible applications of left-over karanjin-free deoiled cake as bio-fertilizer and also as poultry feed.

## Preparation of Protein and Starch-Based Surfactants from Karnaja Seed Cake

Karanja cake is mostly rich in protein, carbohydrate and fibre, but it is unpalatable and may be toxic to cattle due to the presence of several bioactive principles. Karanja cakes contain good ratio of NPK (Table 1) and are reported as useful organic manure for sugarcane, coffee, oranges and paddy for more productivity. In one of the reported studies, it was revealed that one tonne of press cake is equivalent to 200 kg of mineral fertilizer having NPK ratio of 12:24:12. Karanja cakes may also be utilized for studying the controlled release of urea during the in-field studies to save the urea effectively.

In recent times, environmental concerns and statutory regulations have forced the replacement of petrochemical-based surfactants partly with those based on naturally occurring renewable sources. There is a growing interest in the synthesis and formulation applications of surfactants from natural biopolymers. Surfactants based on natural products are always biodegradable and biocompatible. Protein-based surfactants are one of the best examples in this area. However, scientific information for this group of surfactants is very limited. Protein-based surfactants are usually synthesized with amino acids / peptides and fatty acids / alkanolamines as building blocks. The protein from karanja deoiled cake is an excellent source for the preparation of protein based surfactants. IICT has developed a process for the preparation of surfactants directly from proteins using transamidification reaction or after hydrolysis by reacting with fatty acids or diethanolamine. The surfactants properties of these products are quite promising. Similarly work was initiated for the utilization of carbohydrates for the preparation of surfactants.

## Value-Added Products from Glycerol

Glycerol is the main byproduct in biodiesel production and a large quantity of glycerol is expected, which is more than its demand. In order to make Karanja-based biodiesel production economically viable, there is a need to utilize the major by-product like glycerol for the preparation of several value added products. Glycerol is a highly functional molecule and will play a crucial role in future biorefineries as its derivatives find use in sectors such as fuels, chemicals, pharmaceuticals and detergents. IICT has initiated several projects for the preparation of value added products from glycerol.

### Hydrogenolysis and Oxidation of Glycerol

In recent times much research is focused to convert glycerol into several value added products using hydrogenolysis and oxidation. Hydrogenolysis of glycerol gives products such as 1,2-propanediol, 1,3-propanediol, acetol and ethylene glycol, which are commercially more valuable than glycerol. Glycerol oxidation yields a wide spectrum of products such as glyceroldehyde, glyceric acid, mesooxallic acid, tartronic acid and oxalic acid etc.

IICT has mainly focused on the development of catalytic process for the selective reparation of 1,2 propanediol by glycerol hydrogenolysis and mesoxallic and tartronic acid from the oxidation of glycerol. Hydrogenolysis proceeds in two steps, in the first step is the dehydration of glycerol to acetol on acid sites and subsequent hydrogenation on metal sites. Hydrogenolysis of glycerol is studied on noble metal (Ru, Rh, Pd, Pt) catalysts with and without acid as co-catalyst. Among all the noble metal catalysts, Ru is more effective for the hydrogenolysis of glycerol. Copper based catalysts are also useful for the selective hydrogenolysis of glycerol to 1,2 propanediol.

IICT's work is mainly focused on the development of a bifunctional catalytic system. Ru supported on different acidic supports are prepared by different methods and studied for hydrogenolysis of glycerol. Solid acids such as niobia, 12-tungstophosphoric acid (TPA) supported on zirconia, cesium salt of TPA and cesium salt of TPA supported on zirconia were used. The acidities of the solid acid catalysts were measured by temperature programmed desorption of ammonia. The conversion of glycerol depends on the total acidity of the catalysts and there exists a linear correlation between conversion and acidity. The selectivity towards 1,2 propanediol and the glycerol conversion varied with the change in the concentrations of both Ru/C and solid acid catalysts, suggesting a synergetic effect of the reaction. This reaction requires minimum amount of both acid and metal sites to obtain reasonable activity. Different reaction parameters were studied and optimized reaction conditions were established. We achieved about 45% conversion with about 90% combined selectivity towards 1,2 propanediol and ethylene glycol.

Selective formation of 1,2 propanediol by glycerol hydrogenolysis is achieved at low hydrogen pressures using Cu based catalysts. High conversion and selectivity is obtained for the catalyst with Cu ZnO. The presence of small Cu and ZnO particles are required for better activity in glycerol hydrogenolysis. Sufficient amount of ZnO is needed for high conversion of glycerol. The catalysts are highly stable under reaction conditions. The conversion of glycerol and selectivity to 1,2 propanediol depends on the reaction temperature and glycerol concentration. In our studies we achieved more than 94% selectivity towards 1,2 propanediol with about 60% glycerol conversion over our IICT-GH catalyst.

A range of products can be formed by oxidizing glycerol, which include dihydroxyacetone, glyceraldehyde, glyceric acid, glycolic acid, hydroxypyruvic acid, mesoxalic and tartronic acid. The big challenge associated with these catalytic oxidation reactions is to control and direct the reaction pathway to the desired products. Glycerol oxidation is studied by applying different reaction conditions and different metals such as Au, Pd, Pt supported mainly on carbon in order to control the product selectivity to the desired product. It has been shown that by tuning the reaction conditions, particularly the pH, the selectivity to the desired product could be improved. Moreover, the choice of the metal is also critical in directing the reaction pathway. Under acidic conditions, the formation of dihydroxyacetone and hydroxypyruvic acid is predominant, whereas basic conditions lead to the oxidation of the primary alcoholic groups. IICT has initiated work in this direction for the selective preparation of some oxidized products by developing in-house catalysts.

### Preparation of Crown ethers and Dendrimers

Most of the crown ether-based compounds were prepared either from pentaerythritol or epichlorohydrin. IICT has initiated work on the preparation of glycerol-based novel crown ethers using chemo-enzymatic methods for better utilization of glycerol. These molecules may have promising applications such as ion channels, MRI agents, ionic liquids, molecular switches, liposomal gene delivery systems, drug delivery systems and also extraction of radioactive metals. In the initial studies, reaction conditions were optimized for the preparation of crown ether mixtures from glycerol and tetraethyleneglycol. The constancy of the product mixture was also standardized at bench scale. The alkali metal ion extraction studies of these crown ether mixtures was conducted and found to be encouraging.

## Preparation Karanja Oil-Based Lubricant Basestocks

Increased public awareness for a pollution free environment and strict government regulations resulted in the steady increase in the use of eco-friendly consumer products like lubricants. There are a wide range of lubricant base oils in current use which include mineral oils, synthetic oils and vegetable oils. Vegetable oils are recognized as rapidly biodegradable and are thus promising candidates as base fluids in environment-friendly lubricants. Vegetable oil-based lubricants also have good lubricity, high viscosity index, low volatility and are also good solvents for fluid additives. However, they exhibit poor oxidation and thermal stability due to the unsaturation.

IICT has taken up work on development of high performance lubricant base stocks based on karanja oil and karanja fatty acid methyl esters, by simple chemical transformations like transesterification, epoxidation, dihyhydroxylation followed by acylation. Different transesterified products using iso alcohols and polyols ( dihydric and trihydric) and mixed polyol esters using short chain fatty acid methyl esters, along with karanja fatty acid methyl esters, have been prepared. Epoxy oil and epoxy alkyl esters of karanja fatty acids and their derivatives by dyhydroxylation followed by acylation of hydroxy groups with different anhydrides were also prepared for hydraulic fluids and gear oil applications.

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# Bioethanol Production from Biomass at High Temperature

by Sachin Kumar, Pratibha Dheeran and Dilip K Adhikari, Biotechnology Area, Indian Institute of Petroleum, Dehradun

## Introduction

Lignocellulosic biomass is the most abundant renewable resource on earth [1]. Lignocellulosic materials including wood, grass, forest residues, agricultural residues, pulp and paper mill wastes and municipal solid wastes can be used for bioethanol production [2, 3]. Among these resources, agricultural residues such as sugarcane bagasse dominate in terms of tonnage and can serve as feedstocks [3]. Sugarcane bagasse is plentiful in tropical and subtropical regions such as Brazil, India, Thailand, Hawaii and the southern U.S.A. Other lignocellulosic feedstocks include agricultural residues such as corn cob, corn stover, wheat and rice straw; industrial residue such as pulp and paper processing waste; and energy crops such as switch grass [4].

Lignocellulosic materials are comprised of lignin, hemicellulose, and cellulose in varying proportions [5]. The general composition of lignocellulosic biomass is cellulose (35-50%), hemicellulose (20-35%), polyphenolic lignin (10-25%) and other extractable components [4]. The utilization of both cellulose and hemicellulosic monosachharides like hexose, pentose etc. present in a typical lignocellulosic biomass hydrolysate (composition of various lignocellulosic biomass is shown in Table 1) is essential for the economical production of ethanol [6-8]. Therefore, microorganisms which are able to ferment both glucose and xylose are most desirable for an efficient bioconversion of biomass to ethanol [9]. The bioethanol production from lignocellulosic biomass requires two essential steps: saccharification of lignocellulosic biomass to fermentable sugars and fermentation of sugars to ethanol.

Currently bioethanol is produced by fermentation of monomeric sugars by mesophiles worldwide which ferment the sugars at 25-37°C. These mesophiles have certain limitations in fermenting pentose sugars produced from lignocellulosic biomass. However, the thermophiles have certain advantages over mesophiles which could be exploited for ethanol production. Solvent tolerance, energy savings through reduced cooling costs, higher saccharification and fermentation rates, continuous ethanol removal and the reduced risk of contamination have stimulated a search for thermophilic or thermotolerant yeasts [10]. Less energy is required for mixing and product recovery in thermophilic fermentations because of lower viscosity, surface tension, higher vapor pressure and increased solubility of organic compounds [8].

In the present paper we have described the saccharification of sugarcane bagasse by acid treatment followed by the sugar recovery from the hydrolysate by ion exchange chromatography and fermentation of sugars in batch and continuous mode with recycle of thermophilic yeast, *Klyuveromyces* sp. IIPE453 in the temperature range 50°C.

## Materials and Methods

### Microorganisms and Culture Conditions

The strain used for ethanol production, Kluyveromyces sp. IIPE453, was grown in salt medium containing 0.15 g/l di-sodium hydrogen ortho phosphate, 0.15 g/l potassium di-hydrogen ortho phosphate, 2.0 g/l ammonium sulphate, 1.0 g/l yeast extract and 10 g/l glucose with pH 5.5 at 45°C. Fermentation was carried out in a medium prepared in hydrolysate

**Table 1: Composition of various lignocellulosic raw materials**

| Raw materials | Glucose | Mannose | Galactose | Xylose | Arabinose |
|---|---|---|---|---|---|
| Corn stover | 39 | 0.3 | 0.8 | 14.8 | 3.2 |
| Wheat straw | 36.6 | 0.8 | 2.4 | 19.2 | 2.4 |
| Rice straw | 41 | 1.8 | 0.4 | 14.8 | 4.5 |
| Sugarcane Bagasse | 38.1 | — | 1.1 | 23.3 | 2.5 |
| Rice hulls | 38.1 | 3.0 | 0.1 | 14.0 | 2.6 |

containing 0.15 g/l di-sodium hydrogen ortho phosphate, 0.15 g/l potassium di-hydrogen ortho phosphate, 1.0 g/l ammonium sulphate, 1.0 g/l yeast extract with pH 5.0 at 45 to 60°C in batch and continuously made with cell recycle.

### Fermentation Conditions

**Batch fermentation process:** Batch fermentation of sugarcane bagasse hydrolysate and cassava starch hydrolysate were performed in 2 liters Bioflow-110 bioreactor by free cells of *Kluyveromyces* sp. IIPE453 in batch mode. The temperature and agitation were controlled at 50°C and 200 rpm respectively.

**Continuous fermentation process with cell recycle:** Continuous fermentation was performed in 2 litre Bioflow-110 bioreactor by using sugarcane bagasse hydrolysate solution containing glucose and xylose sugars. The hydolysate solution, supplemented with inorganic salts, was fermented using previously grown cells of *Kluyveromyces* sp. IIPE453. The air/ $N_2$ flow in proper ratio was controlled in the bioreactor for in situ recovery of ethanol. The process was performed at different dilution rates, cell mass conc. and temperatures. The pH and agitation were controlled at 5.0 and 250 rpm respectively.

### Hydrolysis of Sugarcane Bagasse

The sugarcane bagasse powder was collected from sugar mill. It was hydrolyzed by sulphuric acid treatment in two stages. In first stage hydrolysis, the sugarcane bagasse was soaked into 2-10% w/w sulphuric acid with solid to liquid ratio 1:10 to 1:4.2. The temperature in the digester was maintained at 100°C temperature for 1h and agitation in the reactor was maintained at 1000 rpm. The aqueous phase was separated from the residual bagasse followed by its washing to collect xylose rich hydrolysate rich stream.

In second stage hydrolysis, 18-65% w/w sulphuric acid was added to residual bagasse taken from first stage hydrolysis. The temperature in the digester was maintained at 80°C temperature for 1 h and agitation was maintained at 1000 rpm. The aqueous phase was separated from the residual bagasse followed by its washing to collect glucose rich hydrolysate rich stream.

### Hydrolysis of Starch Biomass

Hydrolysis of different starch biomasses like soluble starch, cassava, tapioca, sweet sorghum and maize were performed in 1 litre flasks containing 5% starch biomass in 200 ml 0.05M acetate buffer (pH 5.0) and 100 ml crude enzyme (5.29 mg/ml). All the flasks were incubated at 80°C and monitored at 2h intervals until the total starch was hydrolyzed.

### Recovery of Sugars from Hydrolysate

The sugars from the bagasse hydrolysate were recovered by ion exchange chromatography using strong anion and weak anion resins in the ratio of 5:1 to 1:1. A glass column having 100 cm length and 3 cm diameter was packed with 700 g resins. The bagasse hydrolysates obtained in the first stage of hydrolysis containing sugar conc. 35 g/l and sulphuric acid conc. 60 g/l and in the second stage of hydrolysis containing sugar conc. 80 g/l and sulphuric acid conc. 200 g/l. The hydrolysate was passed through the column with flow rate ranging 4-17 ml/min. The sulphuric acid was retained in the column and sugars were eluted through the column. The column was regenerated with water to recover the acid and the acid solution was recycled back for hydrolysis of fresh sugarcane bagasse.

### Analytical Methods

Reducing sugars in media and fermented broth were determined by di-nitrosalicylic acid (DNS) method [11]. Ethanol was determined by using gas chromatography using a Chemito 8600 Refinery Gas Analyser with a 4 m long and 1/8 in dia Porapack column, with Chemosorb 80/60. The sample was injected at 120°C and the oven temperature and flame ionization detector temperature was 150°C and 200°C respectively, using helium as a carrier gas. Ethanol was also determined by colorimetry method [12]. Furfural was measured by Double Beam UV-VIS Spectrophotometer 2600 at 277nm.

## Results and Discussion

### Hydrolysis of Sugarcane Bagasse

In first stage hydrolysis, sulfuric acid was used at different concentrations 2% w/w to 10% w/w and different solid to liquid ratios. The temperature was maintained at 100°C for 1h. The hydrolysate was separated from the residual bagasse and sugars and furfural in hydrolysate were estimated. The maximum 26.14% xylose and 4.6% glucose (47% sugars of total cellulose and hemicellulose present in the sugarcane bagasse) was obtained at 8% w/w acid conc. and at 1: 4.2 solid to liquid ratio, shown in table 2.

In second stage hydrolysis, 6-18% glucose and 2.5-4.64% xylose were obtained, shown in Table 3. The

Table 2. Sugars and furfural (%age of bagasse) recovered in first stage hydrolysis at different acid concentrations

| Acid conc. % (w/w) | Solid to liquid ratio | Xylose % | Glucose % | Furfural % |
|---|---|---|---|---|
| 2 | 1:10 | 9.2 | 0.6 | 0.12 |
| 4 | 1:8 | 13.6 | 0.9 | 0.16 |
| 6 | 1:8.8 | 19.6 | 1.4 | 0.23 |
| 8 | 1:8.3 | 23.1 | 4.4 | 0.31 |
| | 1:5.2 | 25 | 4.6 | 0.41 |
| | 1:4.2 | 26.14 | 4.6 | 0.63 |
| 10 | 1:8.4 | 25 | 5.8 | 0.95 |

Table 3. Sugars and furfural (%age of bagasse) recovered by second hydrolysis at different acid concentrations

| Acid conc. % (w/w) | Acid % w/w (acid/ sugar) | Glucose % | Xylose % | Furfural % |
|---|---|---|---|---|
| 18 | 50 | 6 | 3.5 | 0.21 |
| 26.4 | 75 | 9.7 | 2.5 | 0.16 |
| 33.8 | 100 | 14.5 | 4.64 | 0.14 |
| 65 | 125 | 18 | 3.34 | 0.11 |

maximum 33% sugars of total cellulose and hemicellulose present in sugarcane bagasse was achieved at 65% w/w sulphuric acid conc., when the digester temperature was maintained at 80°C for 1 h, followed by diluting the acid to 20% w/w and again maintaining the temperature at 100°C for ½ h, while agitation was maintained at 1000 rpm. The furfural conc. was negligible.

## Recovery of Sugars from Hydrolysate

The sugarcane hydrolysate, containing fermentable sugars and sulphuric acid, was passed through the column containing ion exchange resins. 95-100% acid free sugars were recovered with strong anion and weak anion mixture in the ratio of 5:2 and flow rate 17 ml/ min. 95% acid was recovered in regeneration of the column. The recovered acid was recycled for further hydrolysis of fresh sugarcane bagasse.

## Ethanol Fermentation from Sugarcane Bagasse Hydrolysate

**Batch fermentation process:** The conc. of thermophilic yeast, *Kluyveromyces* sp. IIPE453 was kept around 10 g/l. Total sugar was consumed within 20 h, shown in figure 1. The final ethanol conc. in broth was 10.2 g/l with ethanol yield 35% and productivity 0.52 $g.l^{-1}.h^{-1}$.

**Continuous fermentation process with cell recycle:** The sugarcane bagasse was fed into the bioreactor with dilution rate 0.075 $h^{-1}$ and 0.1 $h^{-1}$ at 45-60°C. The highest ethanol yield and productivity 42% and 2.3 $g.l^{-1}.h^{-1}$ respectively were obtained at 45°C and 0.1 $h^{-1}$. At 50°C air/ $N_2$ was passed through the bioreactor for in situ recovery of ethanol at different conditions, shown in figure 2. The overall ethanol yield on the basis of total fermentable sugars present in hydrolysate in continuous fermentation with cell recycle at 50°C was 35-38% with ethanol productivity 0.216-1.86 $g.l^{-1}.h^{-1}$. Almost 90% of ethanol was recovered during fermentation on stripping by air/ $N_2$ and five times concentrated ethanol was obtained as compared to ethanol in fermented broth.

## Simultaneous Liquification and Saccharification of Starch Biomass

Different starchy biomasses like soluble starch, cassava starch, tapioca starch, sweet sorghum and maize were hydrolyzed by thermoamylase isolated from *Geobacillus* sp. IIPTN at 80°C, shown in figure 3. The total starch for each substate was hydrolyzed in 10h. The sugar yield obtained on tapioca and sweet sorghum was 81.7% and 58% respectively.

## Ethanol Production from Cassava Hydrolysate

Fermentation was carried out with cassava hydrolysate in batch mode by free cells of *Kluyveromyces* sp. IIPE453, shown in figure 4. The total sugar in hydrolysate was consumed in 138 hrs with productivity 0.09 $g.l^{-1}.h^{-1}$. The ethanol yield obtained was 45% on the basis of fermentable sugars and the overall ethanol yield on dry cassava basis was 33%. The dry cell mass was almost constant throughout the fermentation.

## Conclusion

The overall yield of fermentable sugars in acid treatment was 65-80% (w/w) of total cellulose and hemicellulose present in sugarcane bagasse under different operating conditions. The overall ethanol yield obtained on the basis of total fermentable sugars present in hydrolysate, was 35% in batch process with ethanol productivity 0.52 $g.l^{-1}.h^{-1}$ at 50°C. The overall ethanol yield on the basis of total fermentable sugars present in hydrolysate in continuous fermentation with cell recycle at 50 °C was 35-38%, with ethanol productivity 0.216-1.86 $g.l^{-1}.h^{-1}$. Almost 90% of ethanol in broth was recovered during fermentation on stripping by air/ $N_2$ with five times concentration. The thermoamylase was found very effective for hydrolyzing different types of starch biomasses with the considerable yield of sugar at high temperature.

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***Editorial contd from page 1***

plant for virtually all modes of transportation today, have withstood the test of time. They also would have to yield, and technologies like the fuel-cell, to begin with, may come in. The short term requirement of pollution abatement and energy availability will rule the transition. Technological issues like on-board modules will have to be seen to.

In any of the above issues there would be options and choices, technological complexities, issues of infrastructure requirements, the cost of change, and many more. How do we decide? What is clearly required is a group of wise men who can visualize the future and show us direction. The only clear certainty in this is the need for massive R&D and the will to succeed.

And then only will we know… why the sea is boiling hot and whether pigs have wings!

## Airlines May Use Biofuels on Commercial Flights Within 5 Years

**March 31, 2009**

Airlines may win approval to start using biofuels for their flights as early as 2010 and find commercially viable solutions within five years as they seek to cut carbon emissions and trim dependence on petroleum-based fuel, the International Air Transport Association said.

Recent tests by companies such as Continental Airlines Inc., Japan Airlines Corp., Air New Zealand Ltd. and Virgin Atlantic Airways show that new types of biofuels can work, Paul Steele, executive director of the association's Air Transport Action Group, said today on a conference call from Geneva.

"We expect that some time in the next three to five years we'll have commercial viability of the first versions,' Steele said. "The specification approvals process could be done as early as the end of next year, and then we need some initial commercialization startups."

The interest in new fuels comes as governments push airlines and other industries to trim carbon emissions, blamed for contributing to global warming. Use of biofuels could lead to an estimated 80 percent reduction in emissions during their life cycle and increase energy security beyond current oil supplies, the airline association said.

The organization is now discussing with more than 10 parties the prospects for making available plant sources for use as jet fuel, Steele said. He declined to provide names, citing commercial sensitivity.

Among sources that already have been used in tests are the jatropha scrub plant, which has oil-producing seeds, algae and camelina, a flowering plant that wheat farmers grow. Deutsche Lufthansa AG has a target of using biofuel for 10 percent of its fuel needs by 2020.

*To read more log on to:*
*http://www.bloomberg.com*

## Shell CEO: Biofuels Will Become Bigger Player in Market

**April 2, 2009**

Royal Dutch Shell CEO Jeroen van der Veer said the company estimates that biofuels will make up a tenth of the world's fuel consumption within a few decades, an increase from the current 1%. Shell and other companies have boosted investments in biofuels as countries, including those in the EU, and mandate higher usage of renewable resources.

*To read more log on to:*
*http://www.smartbrief.com*

## Bacteria can Boost Biofuels Growth on Barren Soil

**April 1, 2009**

Scientists have found a way to grow plants for biofuels on unproductive, barren or contaminated soil, without appropriating fertile croplands - just add the right kind of bacteria.

"If we have bacteria that can help plants to grow better, we can then use these soils for the economic production of biofuels," said Daniel van der Lelie, microbiologist at Brookhaven National Lab on Long Island, New York and co-author of a new study on the subject.

Researchers focussed on improving the growth of poplar trees. They are known for their rapid growth and ability to survive in many different climates, both ideal traits for biofuel production.

*To read more log on to:*
*http://www.hindu.com*

## FO Licht: World Does Not Know How to Make New Biofuels

**February 11, 2009**

The world still does not know which crops or plants should be used to produce new generations of biofuels to combat global warming, despite over a billion dollars spent on research, commodity analysts F.O. Licht said on Wednesday.

Governments worldwide want second generation biofuels to replace first generation green fuels produced from foods such as corn, sugar and vegetable oils following bitter controversy about whether biofuel production raises food prices.

In the United States alone, over $1.5 billion has been invested in developing new generation green fuels and the U.S. wants major volumes of new generation fuels to be consumed in the country by 2022, F.O. Licht managing director Christoph Berg said.

But there is still no firm indication of precisely what crops or other plants can be used globally as raw material for second generation biofuels, Berg said.

"There is still no real agreement about what raw material can be used and it is possible that a wide range will be used in different parts of the world," he told Reuters on the sidelines of an F.O. Licht conference on second generation biofuels.

"The raw materials must be available cheaply and could be wood-based, perhaps agricultural waste such as straw or specially-cultivated energy crops such as switchgrass."

The United States may use corn cobs, usually regarded as waste, for cellulose-based ethanol production or switchgrass, a hardy grass variety.

In other countries many materials including wood chips, wheat straw and sugarcane waste could be used.

The technology needed for commercial biofuel production from such material is still unproven and under development, he said.

"There may not be a single dominant technology but a wide range could be developed according to what commodity has to be processed and what pre-treatment it requires," he said.

Second generation biofuels are likely to be produced in market-significant volumes around 2015, he said.

Despite the global economic crisis, both the United States and European Union have signalled strong intentions to develop second-generation biofuels, he said.

"The high profile involvement of public money is likely to help next generation biofuels weather the current crisis," he told the conference.

"While it may become more difficult to obtain new private venture capital, public money is likely to continue flowing."

*To read more log on to:* http://in.reuters.com

## Algae Promoted for Biofuel Use

**April 3, 2009**

The director of the National Algae Association in Texas says tiny waterborne plants may be the future of biofuels.

Association Director Barry Cohen said the plants, commonly referred to as pond scum, are the perfect industry for the United States to invest in as the price of crude oil is expected to rise again and officials search for ways of decreasing dependence on foreign oil and create jobs in "green" sectors, the Houston Chronicle reported Friday.

"My mantra is: What are we waiting for?" Cohen said.

"We have land being thrown at us, not for sale, not for lease, but for free," Cohen said. "Land is a non-issue for this industry."

However, Divya Reddy, an energy analyst for the Eurasia Group in Washington, told the Chronicle it could be 10 years before algae-based fuels are widely available because algae oil production costs $20 a gallon, nearly double the price for other leading biofuel sources.

Cohen said to the newspaper that he expects the price to drop significantly, saying he has seen business plans that estimate the cost to be as low as $1.50 per gallon.

*To read more log on to:* http://www.hinduonnet.com

## Bentley's Biofuel Bargain

**April 5, 2009**

Leaving no doubt that the green car movement is reaching into the furthest recesses of the automobile industry, Bentley Motors – the British-based ultra-luxury brand – has adopted a pro-biofuels policy. The carmaker, owned by Volkswagen, produces some of the world's most expensive automobiles, but that doesn't exempt the company from moving in an eco-friendly direction.

According to "Bentley and the Future of Biofuels," a white paper issued by Bentley in December 2008, "engineering work is already underway and is on target to deliver flexfuel vehicles across our fleet, with the first variant available in 2009." The company is committed to producing "a full range bioethanol compatible vehicles before 2012."

*The Bentley Azure is the least efficient compact car on the market, according to the EPA. The suggested retail price is $334,990.*

***To read more log on to:*** *http://www.hybridcars.com*

## Boeing, Airbus: Downturn Won't Slow Biofuel Plans

**March 31, 2009**

The world's two biggest aircraft makers said Tuesday they were pushing ahead with the development of planes that run on eco-friendly biofuels despite the economic downturn.

Boeing Co. and Airbus say they are not planing on making their own alternative fuels, but are working with ethanol and other biofuel producers to make planes ready for the new technologies in the coming decades.

The sharp drop in oil prices since the start of the global recession has raised concern that the development of fuel-efficient jets may stall. The airline industry is also being squeezed by plummeting passenger numbers.

"The economic downturn doesn't lead to any change in our product strategy," said Christian Dumas, vice president for sustainable development at the Toulouse, France-based Airbus.

He said the airline industry has to think long-term because an aircraft's life span is typically 30 to 35 years

"We are not going to diminish our efforts in research and development," Dumas told The Associated Press in Geneva, where he was taking part in a meeting on aviation and climate change.

***To read more log on to:*** *http://www.businessweek.com*

## Ghana and India Collaborate on Biofuels

**March 26, 2009**

Ghana has attracted the interest of several nations around the world for biofuels projects, the latest being India.

Indian alternative energy companies have entered Ghana and have begun processes to cultivate crops for biofuels in the country.

Currently, Brazilian, Norwegian, Israeli, Chinese, German, Dutch, Italian and Belgian businesses are investing in Ghana to cultivate jatropha and other crops for biodiesel.

India's largest investment in Ghana's biofuels sector is US$45 million (•33 million) by the Ghana subsidiary of Indian company Hazel Mercantile.

The Mumbai-based company which is a distributor of chemicals and petrochemical products intends to cultivate jatropha to produce biofuel.

***To read more log on to:*** *http://www.biofuels-news.com*

## Proceedings of the

# 6th International Biofuels Conference


Biofuels, an emerging and exciting renewable energy option in India, has the capacity to balance the country's ever increasing dependence on fossil fuels. The biofuels industry in India is poised to make important contributions to meet India's energy needs by supplying clean, environment-friendly fuel.

WII, a pioneer in promoting the use of biofuels, organizes an annual International Conference on Biofuels, an initiative to provide a neutral platform for stakeholders from across the world to share their experiences, discuss and debate relevant issues, and help formulate effective policies for the promotion of biofuels in the country.

The 6th International Biofuels Conference was held on March 4-5, 2009 at Hotel Le Meridien, New Delhi, and witnessed participation from eminent personalities of the Biofuels sector. The Proceedings of the conference, with a rich repository of information, would be an important document for industries, institutions, government bodies, NGOs and individuals related to the biofuels sector.

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3. Key Challenges & Issues: Indian Automotive Industry Perspective
   Mr K K Gandhi, *Executive Director (Technical), Society of Indian Automobile Manufacturers*
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