Research in Biotechnology, 4(2): 26-35, 2013 ISSN: 2229-791X
www.researchinbiotechnology.com

Mini Review

Progress of Biorefinery in India

P. Deepa Sankar, M.A. Arabi Mohamed Saleh, C. Immanuel Selvaraj, V. Palanichamy and Rebecca Mathew

School of Bio Sciences and Technology, VIT University, Vellore – 632 014, Tamil Nadu, India

India is one among the world's largest economies and its energy demand accounts for 3.5% of world's commercial energy consumption. According to the International Energy Agency oil demand in India is expected to grow by a factor 2.2 by 2030, increasing the oil import dependency from 69% now to 91%. Rising energy prices and climate change are increasing the demand for biofuel production. The Planning Commission of India recommends replacing 20% of India's diesel consumption mainly by non-edible *Jatropha* oil and *Pongamia*. Biorefinery could be one of the best solutions to overcome the problem. A review on the progress of biorefinery in India is attempted.

Key words : Biorefinery, biodiesel, bioenergy, *Jatropha*, *Pongamia*

Introduction

According to the International Energy Agency, a biorefinery can be defined as a facility that optimizes the integrated production of materials, fuels, energy and chemicals. As stated by the US Department of Energy, Integrated biorefineries employ various combinations of feed stocks and conversion technologies to produce a variety of products, with the main focus on producing biofuels.

World Scenario

The International Energy Agency foresees a growth in global oil demand of 60% from 4,500 billion liters per year in 2002 to 7,700 billion liters in 2030. China and India alone will be responsible for 68% of this increase (International Energy Agency, 2004a). Biofuels could account for 10% of all fuels by 2010, and for 20% by 2020, rising to 50% of a (reduced) consumption of transport fuels by 2050 (Hoogwijk and Broek, 2003; Mathews 2007). At present biofuel production is estimated at 35 billion liters, accounting only for a small part (~2%) of the 1200 billion liters of annual gasoline consumption worldwide. But the contribution of biofuels to energy supply is expected to grow fast with beneficial impacts including reductions in greenhouse gases, improved energy security and new income sources for farmers. However, biomass production for energy will also compete with food crops for scarce land and water resources, already a major constraint on agricultural production in many parts of the world. It will lead to loss of natural habitat and problems will arise as a result of industrial residues (De Fraiture *et al.,* 2008). Countries are waging oil wars in the present

Received: 20.1.2013; Revised: 18.3.2013; Accepted: 20.3.2013

and in the future they may start fighting for water.

India's Need for a Biorefinery

India today is the world's fourth-largest economy of around a trillion dollars (Chidambaram, 2007). India is sixth in the world in energy demand accounting for 3.5% of world commercial energy consumption. Oil demand in India is expected to grow by a factor 2.2 by 2030, increasing the oil import dependency from 69% now to 91%. With the number of vehicles doubling between 2002 and 2020 (International Energy Agency, 2004a), gasoline demand will make up a substantial part of this increase.

Biofuel

Bio-energy, as a replacement for transport fuel can be alcohol, bio-oil or bio-diesel. Biodiesel is registered as a fuel and fuel additive in US with the Environmental Protection Agency (EPA) and is widely used in Europe. Ten per cent of the gasoline demand in 2030 will be met by sugar-based bioethanol, requiring 9 billion liters, an increase by a factor 4.7 compared to 2002 (International energy agency, 2004b; Rosegrant *et al.,* 2006). Two main forms of biodiesel, now sold in the US, are B20 and B100. The production of bioethanol, made from sugarcane, corn, beets, wheat and sorghum, was estimated at 32 billion liters in 2006. Brazil (using sugarcane) and the USA (using mostly corn and soya) are the main producers, accounting for 70% of the global supply (Dufey, 2006). Biodiesel production, derived from oil or tree seeds such as rapeseed, sunflower, soya, palm, coconut or *Jatropha*, was estimated at 2 billion liters in 2005 (International energy agency, 2004b). Germany, France and Italy produce nearly 90% of the global supply, primarily using rapeseed (Dufey, 2006). Interest in deriving biodiesel from palm oil in South East Asia and from *Jatropha* in Nicaragua is growing.

Recommendations of the Planning Commission of India

The Planning Commission of India recommended a major multi-dimensional programme to replace 20% of India's diesel consumption based on the report given by the committee on development of bio-fuel in 2003. It proposed a program to produce ethanol to be blended with gasoline and biodiesel to be blended with high speed diesel. The ethanol is primarily derived from sugarcane and diesel from the tree-based oil crop *Jatropha*. The policy of 5% blending of gasoline with ethanol was made compulsory in 2003 in 9 states, but owing to high costs and red tape the measure was recently abandoned in most of them (Padma, 2005). Five per cent ethanol blending was extended to 20 states and four union territories from 1st November 2006 subject to commercial viability. One objective was to blend petro-diesel with a planned 13 million tons of biodiesel by 2013, produced mainly from non-edible *Jatropha* oil, a smaller part from *Pongamia***.** Eleven million hectares of unused lands are to be cultivated with *Jatropha*. In March 2004 a first portion for a national program on *Jatropha* was released with Rs.800 Crores to support cultivation of *Jatropha* on new fields and plantations of 200,000 ha. This is the first portion of a total program approved with a volume of Rs. 1,500 Crores and 400,000 hectares to be realized within five years. The program intends to replace 5 per cent of diesel consumption by 2006 with 2.6 million tons of *Jatropha* bio-diesel produced on 2.2 million hectares based on yields expected by the Government**.**

The demonstration project consists of two phases, each with 200,000 ha. planted in 8 states of 2 x 25,000 ha. "compact area" each. Each state will have one esterification plant, which is meant to be economical from 80,000 tons of bio-diesel onward, expected to come from 50 to 70000 ha. each. Compact areas in each state will he further subdivided into 2000 ha. blocks of plantation to facilitate supply of planting material, procurement of seed and primary processing through expellers. Expected outputs from 400,000 hectares are meant to be 0.5 million ton of bio-diesel, compost from the press cake, and massive generation of employment (16 million days/year) for the poor. The program is meant to assist to achieve emission standards and climatic targets approved by Government, to improve degraded land resources, and income to 1.9 million poor families at 4 families per ha. on a base of 5 Rs/kg of seed sold. For 2007, when the process was meant to move self-sustained, a scheme of margin money, subsidy and loan is planned to be instituted. Expansion of processing capacities is meant to run on a 30% subsidy, 60% loan, and 10% private capital basis. Additional support for mainly market based "Phase II" from 2007 onwards, was sought from International funding agencies, since the program addresses global environmental concern and contributes to poverty alleviation (Centre for Jatropha Promotion, 2012).

The program emphasizes on creating genetically improved tree species, identification of candidate plus trees, standardization of nursery raising techniques, scientific data for planting density, fertilization practices, planting procedures, technology practices for adoption at grass root level, research on inter-cropping for agriculture, agro-forestry and forestry application, processing techniques including bio-diesel and uses of by-products, utilization of different oils and oil blends including potential additives needed, blending, storage and transport of bio-diesel, engine development and modification, marketing and trade (Centre for Jatropha Promotion, 2012).

Jatropha curcas

According to Jatropha production technology described by Tamil Nadu Agricultural University, Coimbatore, India, *Jatropha curcas* is a multipurpose non edible oil yielding perennial shrub that originated in tropical America and West Asia. It is commonly known as pysic nut or purging nut. *Jatropha curcas* belongs to the family Euphorbiaceae and has the tendency to produce latex and hence animals do not browse the plant. This is a hardy and drought tolerant crop can be raised in marginal lands with lesser input. The crop can be maintained for 30 years economically. The genus *Jatropha* has 476 species and distributed throughout the world. Among them, 12 species are recorded in India. The species *Jatropha curcas* is a promising one with economic seed yield and oil recovery. The oil from *Jatropha curcas* can be used as biodiesel blend upto 20%. However, the refined oil is a qualified neat biodiesel. *Jatropha* is normally propagated through seeds. In one acre, 1000 plants can be planted at a spacing of 2m x 2m. Being a perennial crop, intercrops can be raised in between the rows for the first two years. Crops like tomato, bittergourd, pumpkin, ashgourd, cucumber and blackgram can be grown profitably. Wherever *Jatropha* is cultivated under irrigated condition, the flowering is throughout the year. Economic yield starts from 3rd year end. It is estimated as 3000 kg seeds /acre @ 3 kg of seeds per plant. Oil content is 26.6 to 35.5%. Cost of cultivation per ha. is around Rs.12,500 in the first year and Rs. 5,500 from the second year onwards. Economic projections are around Rs. 30,000 per year in normal soil and around Rs. 6,500 under rain fed conditions (Forest College and Research Institute, 2004).

Pongamia pinnata

Pongamia pinnata known as Karanja is a native of the Western Ghats and is chiefly found along the banks of streams and rivers or near the sea on beaches and tidal forests. It also grows in dry places far in the interior and up to an elevation of 1000 mm. It is a hardy tree that mines water for its needs from 10 metre depths without competing with other crops. It grows all over the country, from the coastline to the hill slopes. The cattle do not browse it. It has rich leathery evergreen foliage that can be used as green manure. From fifth year, it is expected to give economic yields and may continue through to its life of 100 years. When in bloom, the *Pongamia* trees can be used for bee harvesting and honey production (Tree Oils India Ltd., 2012a).

Biodiesel Production Principle

Biodiesel are formed by transesterification of the oil with methanol in the presence of a catalyst (NaOH, KOH) to give methyl ester and glycerol. Hundred kg of oil with twenty four kg of methanol and two and half kg of NaOH approximately yield hundred kg of biodiesel and twenty six kg of glycerine. The methanol and NaOH are premixed and added to the oil, mixed for a few hours, and allowed to gravity settle for about 8 hours. The glycerine settles to the bottom, leaving biodiesel on the top (Tree Oils India Ltd., 2012a).

Advantages of Biodiesel

The Biomass Project on *Jatropha curcas* oil methyl ester based at Nicaragua has compared biodiesel with petrodiesel and European Union standards. Based on the study it was found that *Jatropha* biodiesel could meet up with the European Union standards and fared better than petroleum diesel based on the traits density at 30^{o}c, combustion point, kinetic viscosity, calorific potential, cetane number, ester content, carbon residue and sulfur content. Considering the advantages of biorefinery, Ministry of New & Renewable Energy, India has sponsored reasearch and development projects on bio-fuels to some leading R&D Institutions (Ministry of New and Renewable Energy, 2007). Biodiesel almost completely eliminates lifecycle carbon dioxide emissions. When compared to petro-diesel it reduces emission of particulate matter by 40%, unburned hydrocarbons by 68%, carbon monoxide by 44%, sulphates by 100%, polycyclic aromatic hydrocarbons (PAHs) by 80%, and the carcinogenic nitrated PAHs by 90% on an average (Tree Oils India Ltd., 2012a).

Disadvantages

Substantial biofuel usage induces significant financial costs. Acreage availability could result in conflicts with food production (Peters and Thielmann, 2008; Zhang *et al.,* 2010). Production costs for Indian biofuels are reported in GTZ (Deutsche Gesellschaft fu¨r Technische Zusammenarbeit, 2005). Biofuels based on feedstocks will negatively impact several sustainability criteria (Hoekman, 2009). Modifications are required to the automobiles for use of biofuel. Due to high cold filter plugging point values solidification and clogging of the system occur at low temperatures (Tree Oils India Ltd., 2012a).

Byproducts and its Uses

Glycerine is a major by-product of making biodiesel. The seed husks can be used to make packaging materials. *Jatropha* yields 1t/ha/yr of high protein seed cake (60% crude protein) that can be potentially used as animal and fish feeds and organic matter that could be used as organic fertilizer can fix up to 10t/ha/yr CO_2. Leaf, bark and seed extracts have industrial and pharmaceutical uses (Tree Oils India Ltd., 2012a). Analgesic and antimicrobial activity of methanolic extract of *Jatropha* has been reported (Mosa'd Al-Sobarry *et al.,* 2011; Kalimuthu, 2010).

Ministries, Institutes & Investors Involved in Indian Biodiesel Program

Ministry of New & Renewable Energy (MNRE)

MNRE has sponsored research and development projects on bio-fuels to some leading R&D Institutions. Process parameters for production of bio-diesel from *Jatropha curcas* (Ratanjot) and *Pongamia pinnata* (Karanja) have been optimized; field trials on diesel car have been carried out with different levels of blend of bio-diesel produced from *Jatropha* and *Pongamia* with diesel. The vehicle response has been found to be comparable with diesel vehicles. A 200 liter capacity per batch bio-diesel reactor has been designed, fabricated and developed. The MNRE has prepared a Draft National Policy on Biofuels, which is under consideration by the Government (Ministry of New and Renewable Energy, 2007).

Ministry of Rural Development (MoRD)

MoRD has provided financial support to nine States in 2005-06 for raising of about 18 crore seedlings of *Jatropha* and *Pongamia* and to 18 States in 2006-07 for raising of another 18 crore seedlings. It proposed for the establishment of the National Mission on Biodiesel and launch of its demonstration phase (Phase-I) (Ministry of New and Renewable Energy, 2007).

Department of Bio-Technology (DBT)

DBT has initiated a micro-mission programme on production and demonstration of superior quality planting material of *Jatropha* based on oil content of 30-35% and seed yield of 3-5 tons per ha.. They have raised 22.48 lakh plants under nursery at different places and have initiated R&D projects for improvement of oil quality and seed yield and identification of superior varieties (Ministry of New and Renewable Energy, 2007).

National Oil Seeds and Vegetable Oils Development (NOVOD)

The Ministry of Agriculture through NOVOD Board is promoting *Jatropha* and *Pongamia* under the Scheme of Integrated development of tree borne oil seeds. It has identified elite planting material of *Jatropha* and *Pongamia* under their R&D programme, preserved the germplasm and has sanctioned model plantation of *Jatropha* in 1445 ha. and Karanja in 55 ha. during 2007-08 (Ministry of New and Renewable Energy, 2007).

Indian Council of Agricultural Research (ICAR)

ICAR (2006) under All India Coordinated Research Project on agro-forestry, have initiated efforts in respect of *Jatropha* for collection of germplasm, evaluation trials for growth, seed yield and oil content, hybridization, reproductive biology, agri-silvicultural trials, molecular characterization, biochemical activities and farmers training. It has identified first ever high yielding *Jatropha* variety, SDAUJ I (Chatrapati) for commercial cultivation developed by Sardarkrushinagar Dantiwada Agricultural University. The oil content is 49.2 per cent, the non-edible protein in defatted seed case is 47.8 per cent and the average yield is 1000-1100 kg per ha under rainfed conditions. It is recommended for the semi-arid and arid regions of Gujarat and Rajasthan where annual rainfall is 300-500 mm. The plant attains a height up to 8 feet and shows resistance to all major pests.

Sweet sorghum can be used to produce alcohol and can be blended with petrol at the rate of five percent. BJ 248, RSSV 9, NSSV 208, NSSV 255 and RSSV 56 are the sweet sorghum cultures identified by the All India Coordinated Sorghum Improvement Project. Hybrid Madhura developed by Nimkar Agricultural Research Institute, Phaltan, Maharashtra is a popular hybrid in Sweet Sorghum. (Department of Millets, Tamil Nadu Agricultural University, 2004).

National Bureau of Plant Genetic Resources (NBPGR)

NBPGR has made a systematic collection of *Jatropha curcas* germplasm from four distinct eco-geographic zones of peninsular India in 2005 (Sunil *et al.,* 2008). It involved recording of passport data, documentation of important plant traits *in-situ*, eco-geographic parameters and assessment of variability. A method has been developed for identification of superior lines by assessing the phenotypic traits of plants recorded *in-situ* which facilitates selection of promising accessions for multi-location evaluation and hastens the process of utilization of germplasm.

Tamil Nadu Agricultural University (TNAU)

With the technical support of TNAU, ICAR and Department of Agriculture, agencies such as World Bank, Rockefeller Foundation, Appropriate Technology International, Intermediate Technology Development Group-USA, UK & Biomass Users Network are supporting the promotion of *Jatropha* (Tree Oils India Ltd., 2012). High yielding types of *Jatropha* are being collected and evaluated for development of hybrids. Types from Africa (Madagascar, Zimbabwe and Cape Verde) are considered ideal for cultivation. Forest College and Research Institute, TNAU maintains a germplasm species collection of *Jatropha curcas, Jatropha curcas* (nontoxic), *J. curcas x J. integrerrima, Jatropha gossypifolia, Jatropha glandulifera, Jatropha tanjorensis, Jatropha multifida, Jatropha podagrica and Jatropha integerrima* (Neelakantan, 2004). It produces and supplies quality planting material to State Agricultural Department, Horticultural Department, rural development agencies, Railways, non-governmental organizations, agro-industries and farmers. TNAU has launched a pilot plant for biodiesel with a capacity of 250 kg oil/day which requires a command area of 25 ha (Tamil Nadu Agricultural University, 2012). Glycerol produced as bi-product is 55 kg/day. Cost of the unit is Rs.1, 50,000. Cost of operation is Rs.3/l of diesel (excluding *Jatropha* oil cost).

The Government of Tamil Nadu launched waste land development project and introduced *Jatropha*, sweet sorghum and sugar beet which have greater potential for biofuel production. Tropical sugarbeet (*Beta vulgaris* Var. *Saccharifera* L.) varieties *viz*., Pasoda, H1 0064 and Doratea are gaining popularity in Tamil Nadu for the production of ethanol which can be blended with diesel to the extent of 10%. The bi-products *viz*., beet top can be used as green fodder, while beet pulp and filter cake can be used as cattle feed. Sweet sorghum has emerged as a supplementary crop to sugarcane in dry land pockets for the production of ethanol. TNAU has developed a Sweet Sorghum variety VMS 98003 with a cane yield of 45.7 t/ha and ethanol yield of 3.6 kl/ha which matures in 100-110 days (Soil and Crop Management Studies, Tamil Nadu Agricultural University, 2004).

Indian Institute of Technology (IIT), Delhi

Research on the transesterification of Karanja oil is being undertaken at IIT, Delhi. Naik *et al.* (2008) have reported mechanisms of dual process adopted for the production of biodiesel from Karanja oil containing FFA up to 20%. Sometimes the oil is contaminated with high free fatty acids (FFAs) depending upon the moisture content in the seed during collection as well as oil expression. The first step was acid-catalyzed esterification by using 0.5% H_2SO_4, alcohol 6:1 molar ratio with respect to the high FFA Karanja oil to produce methyl ester by lowering the acid value, and the next step was alkali-catalyzed transesterification. The yield of biodiesel from high FFA Karanja oil by dual step process was observed to be 96.6–97%. Meher *et al.* (2006) have studied on transesterification of Karanja oil with methanol for the production of biodiesel. The reaction parameters such as catalyst concentration, alcohol/oil molar ratio, temperature, and rate of mixing were optimized for production of Karanja oil methyl ester (KOME). The fatty acid methyl esters content in the reaction mixture were quantified by HPLC and

HNMR method. The yield of methyl esters from Karanja oil under the optimal condition was 97–98%.

National Botanical Research Institute

Scientists from National Botanical Research Institute *viz.,* Ranade *et al.* (2008) have reported on the diversity amongst the accessions of *Jatropha*. Two single-primer amplification reaction (SPAR) methods were used for this purpose. The accessions from the North East India were most distant from all other accessions in UPGMA analysis. The NBRI, Bhubaneshwar and Lalkuan accessions were more related to each other. The UPGMA tree clearly shows well-separated accession groups: NBRI, Bhubaneshwar, North East, Lalkuan and Outgroup. The study suggests that this relatively recently introduced plant species shows adequate genetic diversity in India and parental lines can be chosen for adaptability trials and further improvement.

Central Arid Zone Research Institute

Azam *et al.* (2005) of Central Arid Zone Research Institute have studied on fatty acid profiles of seed oils of 75 plant species having 30% or more fixed oil in their seed/kernel. Fatty acid compositions, iodine value and cetane number were used to predict the quality of fatty acid methyl esters of oil for use as biodiesel. Fatty acid methyl ester of oils of 26 species including *Azadirachta indica*, *Calophyllum inophyllum*, *Jatropha curcas* and *Pongamia pinnata* were found most suitable for use as biodiesel and they meet the major specification of biodiesel standards of USA, Germany and European Standard Organization.

Energy and Resources Institute (TERI)

The institute undertook the project on National Mission on Bio-fuel sponsored by the Ministry of Rural Development and completed it on June 2005 and Biofuels 2012-Vision to Reality Sponsored by Hindustan Petroleum Corporation Limited; Ministry of Environment and Forests; Ministry of Rural Development; Oil Industry Development Board; Tata Motors Limited and completed in 2006. Ongoing projects include Genetic enhancement of *Jatropha* for Department of Biotechnology, Feasibility study on *Jatropha* plantation and bio-diesel production for North West Chemicals and Fertilizers and Molecular characterization of *Pongamia pinnata* germplasm from NCT of Delhi for Department of Science & Technology.

Centre for *Jatropha* Production & Biodiesel (CJP)

CJP claims to be a global authoritative agency for scientific commercialization of *Jatropha*. It designs and implements growing of *Jatropha curcas* from desert of Churu Rajasthan to entire India and worldwide in a structured agri-supply chain, value additions of *Jatropha* seeds and research. It provides support/services from "Soil to Oil" for development & establishment of the non-food bio-fuel crops. Its mission is to cultivate 100,000 hectares in India with *Jatropha* to produce 1 million metric tons of oil to supply bio diesel refineries domestically & worldwide. It aims to empower rural farmers to trade-out of poverty through commercial, renewable & sustainable *Jatropha* farming in India. The centre has designed a *Jatropha* Agri-Extension Kit to enable farmers to cultivate the crop. It conducted its 2nd Global *Jatropha* Hi-Tech Agricultural Training Programme in India from July 14-18, 2008 (Centre for Jatropha Promotion, 2012).

Tree Oils India Limited (TOIL)

Tree Oils India Limited (TOIL) was established in 2003 to develop environment friendly and sustainable energy systems based on plant sources, contribute to waste land utilization and employment of farmers. TOIL is primarily engaged in manufacture of biodiesel from non-edible tree oils such as *Jatropha curcas* and *Pongamia pinnata* in waste lands in Medak district of Andhra Pradesh, India. In order to facilitate commercial production of tree based oils on a large scale TOIL established a 120 acre research and development farm in India in 2003. The plantation consists of 60 acres of *Pongamia* (Indian Beech), 40 acres of *Jatropha* (Physic Nut), 5 acres of Moringa (Drumstick), 2 acres of Azadirachta (Neem), 1 acre of Sapindus (Soap nut) and 1 acre of Simarouba (Paradise). TOIL has also planted Madhuca (Mahua), Aleurites (Candle Nut) and Sapium (Chinese Tallow) for research purposes. The focus has been on developing an integrated tree based oils farming system that can be adopted by contract farmers within the next five years. TOIL is planning to set up a 2 ton per day (TPD) capacity biodiesel plant, depending upon the availability of seed. In due course, TOIL proposes to set up number of such units in different parts of the country and network them. The target is to have 50,000 acres of plantation and 100 TPD of biodiesel production (Tree Oils India Ltd., 2012b).

D1 Oils

UK-based D1 Oils is the world's leading developer of *Jatropha* biodiesel. Although its biodiesel refinery in England currently relies on soya oil from Brazil, D1 says it will soon switch to *Jatropha* oil, sourced from its own plantations. D1's *Jatropha* plantations are located in Saudi Arabia, Cambodia, Ghana, Indonesia, the Philippines, China, India, Zambia, South Africa and Swaziland. D1 is now working on the development of high-yielding *Jatropha* varieties, with much of its breeding work focusing on India, an important centre of *Jatropha* diversity and research (GRAIN, 2007).

VIT University

VIT University has initiated research in the area of biorefinery by greening the adjacent arid mountains using *Jatropha* and *Pongamia* and is to collaborate with TNAU for developing the program. The School of Biotechnology, Chemical & Biomedical Engineering is actively participating by running a funded project on "Enzyme catalyzed biodiesel production from non-edible oils" (Research Activities, VIT University, 2012). The Energy Centre at VIT has the capacity of a biodiesel plantation and extraction facilities (Energy centre, VIT University, 2012).

Crescent Engineering College

Research on the use of *Pongamia* biofuel is progressing in Crescent Engineering College. Performance and emission analyses were carried out in an unmodified diesel engine fueled with *Pongamia pinnata* methyl ester (PPME) and its blends with diesel by Sureshkumar *et al.* (2008). The results reveal that blends of PPME with diesel up to 40% by volume (B40) provide better engine performance (brake specific fuel consumption and brake specific energy consumption) and improved emission characteristics.

Other major players include Indira Gandhi Agricultural University, Punjab Agricultural University, Indian Oil Corporation, Indian Institute of Petroleum, Indian Institute of Chemical Technology, Mission Biofuels, Kumaraguru College of Technology, Godrej Agrovet, Kochi Refineries, Biohealthcare, The Southern Online Biotechnologies, Jain irrigation System, Natural Bioenergy and Reliance Energy *etc.,* Petroleum Conservation Research Association (2012) has launched Bio-Diesel Bank to facilitate the flow of information to the National Biofuel Centre operational at its corporate office.

Conclusion

Bioenergy is being mass produced around the globe. It helps to solve the energy crisis. India, a major energy consumer, is also trying to solve its energy requirements with the production of various forms of energy including bioenergy. Though production of bioenergy poses numerous disadvantages humans do gamble with it to maintain the economy.

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