Lecture Series on

Next Generation Fuel (NexGen Fuel)

Phase 2

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Distinguished Speaker

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Organized by

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Dr. Debabrata Das pursued his doctoral studies from Indian Institute of Technology (IIT) Delhi and post-doctoral research work at University of Utah (UU), USA. Presently, he is a **INAE-AICTE Distinguished Visiting Professor** of SRM Institute of Science and Technology, Chennai and Heritage Institute of Technology, Kolkata. In addition, he is the **Scientific Advisor** of M/s. Dhampur Sugar Mills Ltd., New Delhi. He was also associated as **MNRE Renewable Energy Chair Professor** for three years and **Professor** for 32 years at IIT Kharagpur. He is actively involved in the research of hydrogen biotechnology for a period of more than twenty years. His commendable contributions towards development of a commercially competitive and environmentally benign bioprocess for the biohydrogen production from organic wastes using both mesophilic and thermophili cmicroorganisms added a new dimension to the field.

He has more than **170** research publications in the peer-reviewed journals and contributed more than **38** chapters in the books published by International publishers. He has been awarded with 2 international patents and applied for 4 more. He has been awarded as Fellow of Indian National Academy of Engineering (2015) and Fellow of International Association of Hydrogen Energy (2016). He has been honored with a number of prestigious awards and facilitation by many international and national societies. A few of them are Akira Mitsui Award of International Association of Hydrogen Energy at WHEC2008 at Brisbane, Australia, Malaviya Memorial Award2013 of Biological Research Society of India at Jawaharlal Nehru University, New Delhi.

Schedule

Date	Time	Topic
04.04.22	12:00 Noon – 1:15 PM	Advanced biofuel production processes using renewable resources
06.04.22	12:00 Noon – 1:15 PM	Fundamentals and technology advances of biohydrogen production processes
07.04.22	12:00 Noon – 1:15 PM	Effect of bioreactor configurations on the biofuel production
11.04.22	12:00 Noon – 1:15 PM	Thermodynamic and Kinetics of Biomethanation process
13.04.22	12:00 Noon – 1:15 PM	Biohythane: Fuel for the future
13.04.22	12:00 Noon – 1:15 PM	Scale-up and Case studies of biofuels production processes

Abstracts

Lecture 1

Advanced biofuel production processes using renewable resources

Energy plays an important role in human society because it contributes to the technological developments and social progress of a country. This contribution has great impact on the quality of our life. Due to rapid industrialization and urbanization, energy consumption has been increased extensively. According to the International Energy Agency (IEA), the world's primary energy need is expected to grow by 55 percent between 2005 and 2030, at an average annual rate of 1.8 percent. At present, the world energy needs are supplied mostly through fossil fuels such as coal, natural gases, and petrochemical sources that will be exhausted in less than 100 years as predicted by the World Energy Forum. Fossil fuels also are responsible for the greenhouse effect resulting from the generation of carbon dioxide. Renewable energy sources as alternatives to fossil fuel energy sources may play a vital role in overcoming the energy shortage problem in future. Renewable energy sources not only help to meet our energy demand but also safe guard our environment. Biomass is considered an important renewable energy source. The emergence of biofuel production from biomass has endured since the dawn of early civilization. Solid biofuels such as wood and cow dung have been used for cooking and heating purposes for ages. Similarly, liquid biofuels have been used in the automotive industries since its inception. Recent development of different biofuels production processes from renewable resources will be elucidated.

Lecture 2

Fundamentals and technology advances of biohydrogen production processes

Hydrogen is the fuel of the future mainly due to its highest heating value, recyclability and nonpolluting nature. Biological hydrogen production processes are found to be more environment friendly and less energy intensive as compared to thermochemical and electrochemical processes. They are mostly controlled by either photosynthetic or fermentative organisms. The microorganisms and biochemical pathways involved in hydrogen generation processes are playing important role. Several developmental works will be discussed. Immobilized system is found suitable for the continuous hydrogen production. Fermentative hydrogen production processes have some edge over the other biological processes.Several pilot plants have been successfully demonstrated throughout the world to find out the viability of the biohydrogen production processes.

Lecture 3

Effect of bioreactor configurations on the biofuel production

The adverse effects of using conventional fossil fuels have triggered an exponential increase in biofuel production from biomass. The process economics of biofuel production is dependent largely upon the type of reactor used during the process. Different configurations of reactors have been developed over the years depending upon the type of gaseous biofuels, conversion technology, and the composition of feedstock used. The simplest design for the production of any biofuel is the batch reactor, which requires less initial capital and infrastructure investment. It can accommodate different types of feedstock and does not require stringent operating conditions. However, it has various disadvantages such as low productivity, large downtime, variation in product quality, and intensive labour and energy requirements. To address these issues continuous flow systems have been developed, which result in consistent product quality and low capital and operating costs per unit of product. Other reactor configurations that have been developed for efficient gaseous biofuels production include packed bed reactors, fluidized bed reactors, and upflow anaerobic sludge blanket reactors. In this lecture, a comprehensive overview of the various reactor configurations used for the biofuels production is presented along with their potential benefits and drawbacks. The reactor is the heart of any biochemical process. Reactor configurations play a very important role in chemical and biochemical processes. For example, in case of substrate inhibition fed-batch usually is preferred, whereas for product inhibition plug flow reactor is recommended. But the operation of a plug flow reactor poses some problem particularly to maintain no back mixing condition and plug flow, which is also known as piston flow. However, this can be overcome by using cascade reactor or continuous stirred-tank reactor (CSTR) in series. The major problem with the CSTR or chemostat is the cell washout. If the cell mass wasting from the reactor is more than the rate of cell growth, the situation of cell wash out will occur when no cell is present in the reactor. Cell recycle and cell immobilization are the techniques by the virtue of which these problems can be avoided. The major problem with the immobilized whole cell reactor is the gas hold up problem. This problem may be overcome by modifying the reactor configuration such as by use of rhomboidal and tapper. A critical analysis of these reactors is needed for finding out the suitability of the process for gaseous fuels generation such as methane and hydrogen. This chapter deals with the analysis of these reactors.

Lecture 4

Thermodynamic and Kinetics of Biomethanation process

Anaerobic digestion, or biomethanation, is a process by which organic wastes are convertedto methane and CO_2. Besides the gaseous energy recovery, this process producesdigested organic residues that can be used as an organic fertilizer due to the presenceof ammonia and humus. This residue also increases the water retention properties ofthe soil. Besides methane and CO_2, the biogas also is comprised of N_2, H_2, and H_2S inminor quantities. Various industrial and domestic organic wastes can be treated usingthe biomethanation process. The anaerobic digestion process is favoured over otherwaste treatment processes because it produces renewable energy in the form of methaneand thus can improve the overall economy of the process. The organic materials remain either in solid or in liquid forms andmay be used as substrate for the biomethanation process. The chemical composition ofeach of these materials varies. In the last several decades, emphasis has been given tothe study of different raw materials individually and in their combinations.Biomethanation process comprises of several metabolic steps. Thermodynamics of the process gives not only comparative information on the favourable step of the metabolic process but also to what extent the reaction will take place. Kinetics of the Biomethanation processis important for the scaling up of the process.

Lecture 5

Biohythane: Fuel for the future

For the quest of clean, renewable energy solutions, many technologies have been explored, viz., bio-oil production by hydrothermal liquefaction, biomass gasification, pyrolysis of petroleum for methane production, etc. One such concept that has gained importance in recent times is hythane (hydrogen and methane). The biological process for clean energy gaseous energy generation encompasses biohydrogen and biomethane production. The carbon footprint of biohydrogen and biomethane production processes is still less compared to chemical processes. Biohydrogen can be produced from organic wastes at ambient temperature and atmospheric pressure, thereby generating a sustainable process that subsequently helps in waste stabilization. In addition, biogas generation process is mainly governed by two groups of microflora: acidogens and methanogens. Little information is available to find out the suitability of acidogens on hydrogen production, which may be considered potential microflora in the dark fermentation process. Thus, the dark fermentation process is considered a most promising method for biohydrogen production amongst all other processes. The spent media of the dark fermentation process contains a significant amount of short-chain fatty acids, viz., acetate, butyrate, propionate, etc. These volatile fatty acids are suitable substrates for methanogens. Therefore, integration of the biohydrogen with biomethane processes under the eponym of “biohythane” could help in the improvement of gaseous energy recovery. The integration of the biohydrogen and biomethanation processes is challenging, and an immediate emphasis is required to develop human resource, expertise, and infrastructure related to it.

Lecture 6

Scale-up and Case studies of biofuels production processes

Energy crisis and the environmental pollution are major concerns in the world. Bioenergy-producing industries are playing a significant role to reduce the net carbon emissions by consumption of biofuels. Biofuels are available in three different forms: solid, liquid, and gas. Solid biofuel mainly include dry lignocellulosic biomass. There are two major problems for the use of solid fuels: transportation and energy conversion efficiency. However, in the case of liquid and gaseous biofuels, these problems can be minimized. Bioenergy sources mainly are renewable in nature. The high production costs, complex conversion technologies, high energy input, and limited resources are among the few concerns associated with other renewables such as wind, solar, and hydrothermal. The main alternative to fossil fuels is biomass. It is estimated that a four time increase in present bioenergy production (150 EJ/year) (1 EJ = 1018 J) can lead to an almost 50% greenhouse gas (GHG) reduction by 2050 (World Energy Resources Bioenergy (2016). The most common biofuels that are produced commercially include ethanol and biodiesel, which require conversion of food-based crops such as grains and oilseeds (first-generation biofuels). Other non-food-based crops such as forest and agricultural wastes, and residues are potent raw materials for biofuel production, but their main disadvantage is high energy input. High energy input is the main problem when using lignocellulosic feedstocks. In addition, these feedstocks require pre-treatment for the separation of lignin of which most is not biodegradable. The crystallinity of the cellulose molecules also play an important role in its biodegradation. However, the lignocellulosic feedstock can be converted to fuels by the thermochemical process. Solid food wastes can be easily converted to methane and hydrogen by an anaerobic digestion process. Attempts have been made to convert lignocellulosic feedstock, oil seed, and algae to liquid fuels such as ethanol, biodiesel, and butanol on a large scale.