Bio-Energy

Introduction

An important problem of modern human society is the quest for new energy sources. Until quite recently, the technological progress of human civilization depended on extensive exploitation of fossil energy sources such as coal, oil, gas and in the last decades uranium. In recent years, considerable efforts have been made to economize these non-renewable energy resources and to decrease the environmental pollution caused by their consumption. It is one of the basic objectives of the B.I.O.1,2 to sensitize experts in the field of energy who in turn will look for alternative sources of energy, thereby removing the "dependency on non- renewable resources in order to achieve a sustainable world economy."3 In this context, considerable importance has been attached to the research and development of directions involving alternative renewable and ecologically clean energy sources4,5,6 such as semi- conductor solar batteries, aeolic energy, hydrothermal energy, fusion energy, as well as energy obtained with the use of living organisms and bio-energy.

Bio-Energetics and Bio-Energy

Bio-energy is of particular interest from the biopolitical point of view. Bio-energy is inexpensive. It can be readily used on the local scale, with relatively low capital investments required. This can be best exemplified by bio-gas (or bio-methane) production7-9 from industrial, municipal or agricultural waste. Currently, over 10 million small bio-reactors for producing bio-gas are operated by peasants in the rural regions of China. This simple and economical technology is being increasingly employed throughout the Third World. At the same time, the industrially developed countries such as Germany and France are developing intensive methods of large-scale bio-methane production.

Bio-energetics is the branch of biology providing the conceptual foundations for bio- energy production. Bio-energetics deals with the processes of energy accumulation and consumption taking place in a living organism. The energy used by a living organism derives from light (photosynthesis) or from a chemical substrate decomposed or oxidized (fermentation, respiration). These activities of living organisms are discussed in more detail in other sections of this syllabus.

Methods of Technical Bio-energetics

The production of energy for the benefit of man on the basis of bio-energetical systems is referred to as technological (or technical) bio-energetics.8,9 It involves all the three types of bio-energetical processes considered above. Combustible products of these processes are used as renewable energy resources as fuel and as raw materials for chemical industry. The products of bio-technology used as renewable fuel can contribute to developing waste-free production cycles.10,11The most important processes of bio-fuel production are given below:

- production of ethanol from materials containing sugar, starch or cellulose by yeast or bacteria. Practiced in the course of several millennia in the Old World with the use of baker's yeast and in the New World by means of the bacterium Zymomonas mobilis. The process of ethanol fermentation underlying the technology considered is carried out by microbial species which have not traditionally been used. In Japan, a bacterium has been bred which produces ethanol from paper or rice straw without any pretreatment of these materials. Ethanol is being now increasingly used as ecologically clean motor fuel as such or as additive to gasoline. A mixture containing 10-20% of ethanol is called gasohol ,
- production of butanol and acetone using fermenting bacteria of the genus Clostridia. The bacteria involved carry out a biphasic fermentation. In the first phase, organic acids are accumulated. The second stage yields acetone and butanol, valuable fuels and raw materials for chemical industry. Up to the present, it remains a challenging task to maximize the yield of the useful products and to minimize the production of unwanted acids;
- production of hydrogen. This process is catalyzed by specific enzymes hydrogenase and nitrogenase. Hydrogen evolution is linked to photosyn thesis in algae and phototrophic bacteria, whereas other bacteria produce hydrogen in the dark as a result of respiration or fermentation. The technology considered has been tested only on the laboratory scale. Both whole cells of hydrogen-producing micro-organisms as well as their components have been employed;
- production of methane or bio-gas, which involves a mixed culture of microbes, the so- called methanogenic association. It removes bios-threatening waste and produces valuable gaseous fuel, a substitute for natural gas. Different technological designs of this process have been suggested ranging from a simple pit filled with garbage or cattle manure to elaborate bio-reactors equipped with with sensors and utilizing microbial cells fixed on solid materials. However, bio-gas can be obtained using simple set-ups like the subterranean Chinese tanks attached to the reservoir for collecting bio-gas. A promising design of methane production involves SAHEL digestors-bioreactors producing 5 to 7 cubic meters methane per day from straw;12
- production of long-chain hydrocarbons (bio-oil) from the biomass of marine microscopic algae Botryococcus braunii which have been

shown to accumulate a quantity of hydrocarbons amounting to 75% of their dry weight. These algae can be grown in pure culture in a bioreactor. But they can be also cultivated within a natural ecosystem in a lake, pond, or lagoon;

- diverse methods of fuel production from plant biomass which hopefully will gradually supplant the crude method of burning wood still practiced in less developed countries. In particular, yeast can make ethanol from pre-hydrolysed wood cellulose and hemicelluloses; methanol can be produced from wood chemically. A valuable fuel with high specific combustion heat can be obtained from plant oils by etherifying them. Also, natural plant oils can be used as motor fuel. For instance, the plant pourghere (Jatropha curcas) occurring on the Indian Ocean coast contains considerable amounts of combustible oil in its seeds. This oil is inexpensive, easy to extract from the seeds and, if extensively used as carburetor oil, could free the population of a number of regions from their energy constraints12. The biomass of water hyacinth abundant in South Asia can be efficiently converted into methane by methods of ecosystem bio-technology, as mentioned above;
- studies are in progress which are aimed at direct generation of electric current by means of living cells or their components, primarily enzymes. These systems termed bio-fuel cells are expected to compare with semiconductors in terms of efficiency

Application of Ecosystem Bio-technology for Bio-Energy Production

Principles of ecosystem bio-technology have been applied to the construction of materially closed or semi closed systems which include human beings and photosynthetic organisms and are to some extent independent on the entry of the nutrients and oxygen from outside the system.8,9 A number of such systems incorporating algae or higher plants such as wheat and carrot have been successfully tested in long-term field studies.

None of the components of the methanogenic association discussed above can convert complex organic substrates (garbage, cattle manure, water hyacinth biomass, etc.) to methane per se. They can carry out this feat only in cooperation. Therefore, this technology is another example of ecosystem bio-technology, as it implies construction of an ecosystem which is capable of methane production. This process is of special promise for the future, as it belongs to the double-effect technologies.

"For the future, technology under the condition of energy and resource conservation will be more frequently used and will be more important. For work to be done until the product is complete, use of less material and less energy will be desired. For that purpose, it is necessary to make the transition take place at low speed...Transition utilizing organisms is slow speed compared to mechanical process,...but is worthwhile if energy and material consumption is low."13

Thus, employment of bio-energy apart from being a promising alternative to the use of dwindling stocks of fossil fuel is expected to have an interesting psychological and societal side effect. It will promote a systemic, integral vision of living things on Earth as components of energy-converting ecosystems, with human beings as component parts. Thereby, technological bio-energetics is expected to contribute to fostering the main goals of biopolitics,1-3 to maintaining and promoting the bio-environment.

Objectives

- to illustrate the main mechanisms of energy conversion by diverse living organisms in relation to their uses for renewable energy production;
- to outline the most important methods of producing fuels by means of living organisms and to relate technological bio-energetics with bio-technology;
- to highlight the potential benefits of ecosystem bio-technology in application to the production of bio-energy.

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