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MODERN TECHNOLOGIES AND INSTALLATIONS DESIGNED TO INDUSTRIAL SCALE CULTIVATION OF MICROALGAE FOR OBTAINING ALGAL BIOMASS

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Abstract: Nowadays, the biomass produced by the energetic plants is rather criticized, because these plants need large culture surfaces, thus competing with the agricultural land allotted to food production. One of the current trends of scientific biological researches with practical goal is the cultivation of algae designed to obtain the algal biomass as an important raw material used in biotechnologies for production of alternative fuel. This paper presents the most up-to-date technologies and installations for industrial cultivation of microalgae together with INMA researches results materialized in the installation of open culture systems growing, of waterfall type.
Keywords: algae, cultivation technologies, biomass, biofuels

INTRODUCTION

Production of vegetal biomass at large scale means to cultivate numerous species of plants. According to specialty literature (*R. Şumălan. 2011),* biomass is a very important component of carbon cycle and the carbon from atmosphere is turned into biological matter (biomass) by photosynthesis. By vegetal matter combustion, the carbon returns into the atmosphere as carbon dioxide. Biomass is biodegradable and renewable. Production of biomass is continuously extending due to increased interest in alternative energy sources.

Biomass is a renewable energy that supplies biofuels, generally of solid type and liquid biofuels. (*I.R. Pecingina. 2011*).

Biofuels are fuels produced by bio-renewable sources coming from nature that, after their combustion in the engine produce less noxious emissions to the environment.

According to European and national laws and literature (*Cărăuş I. 2007; I.R. Pecingina. 2011; M. Pavnutescu. 2011*) on improving environment quality, the general goal is to limit the quantity of fuel related to harvests and orient towards the biofuel coming from non-food sources, such as *waste and algae*.

The higher price of oil, as well as, the growing food crisis has led to an increased interest in algae culture, from which result vegetal oil, biodiesel, bioethanol, biobutanol and other fuels. This new energy source has many advantages among which the fact that it does not harm the environment, when storing it randomly and it does not affect fresh water stock, being biodegradable.

According to quantitative criterion, algal biomass represents about 20% out of world aquaculture production (*S. Dobrojan and. so on, 2016*). The advantages and very good results obtained by applying at different fields algal biomass make imperative the necessity of growing algae.

Recently, large quantities of red, brown and green and blue-green algae are being cultivated. Algae make efficiently use of solar energy conserving it in biomass. (*Marchin T.. s.a.. 2015*).

More recently, algae industrial growing increased in the whole world as a source of renewable fuels. According to estimates, from the 50,000 of microalgae species cultivated, about 10 are being grown at industrial scale in order to obtain some products such as: Spirulina, Crypthecodinium cohnii, Chlorella, Dunaliella salina, Ulkenia sp, Haematococcus pluvialis, Schizochytrium, Aphanizomenon flos-aquae, Euglena and Odontella aurita.

Among the 10 species industrially cultivated, the species Chlorella, Spirulina and Cryptecodinium have the biggest contribution, as it results from the studies of specialists in domain. (*S. Dobrojan s.a.. 2016; Egardt J. Lie O. 2013*).

A strategic trend that is more and more spread lately is based on obtaining biodiesel and biogas from algal biomass.

MATERIAL AND METHOD

Large-scale cultivation of algae is achieved by means of various installations in terms of size, design and shape. There were designed very simple installations consisting of channels of small depth made in the soil, lined with polyethylene foil, but also special installations of big size were built, these ones comprising concreted circular or other shape basins endowed with systems of agitation of algal suspension, aerating systems, harvesting systems and even devices of adjusting the growing parameters (including automated systems).

Industrial-scale cultivation of microalgae is being achieved by different systems, as they are shown in the scheme from Figure 1.

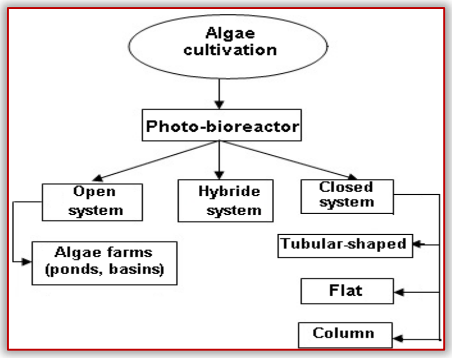


Figure 1 – Schematic representation of algae growing systems

— Open algaculture systems are recommended for areas of warm climate.

From practical reasons, algae should be grown in special farms and they should not be harvested in their natural environment, namely in the sea. Taking into account that the open systems might be contaminated by bacteria, biomass is mainly designed to obtain biofuel.

A large capacity farm endowed with circular basins, built in Taiwan is shown in Figure 2.

Its basins have approx. 45 meters diameter and the algal slurry depth is about 50cm; the algal culture is agitated by means of a mobile radial arm that also injects pressure air into the algae growth medium, where carbon dioxide of 20% was added for *Chlorella* and 10% for *Spirulina* culture.

Figure 2 – Industrial-scale installation for growing microalgae (from Hills, 1981)

— Closed systems of industrial scale algae culture consist of closed bioreactors placed vertically or horizontally, the algaculture being grown in recipients as sacks, bags, tubes, columns, flat constructions, etc.

Algae growth in closed cells (bags) and columns, Figure3 was developed as an alternative method of producing algae more rapidly and more efficiently than in the open systems.

Figure 3 – Algae cultivation in plastic bags

Within the system of algae culture on vertical, the algae are laid in transparent plastic bags, this way being exposed to sun rays on both sides. The bags with algae are hung from the ceiling and the roof protects them against the rain. Due to sunlight exposure algae productivity increases, as well as extracted oil yield. At the same time, algae contamination must be avoided. Another type of bioreactor is the tubular reactor, built of transparent pipes placed in parallel. In Figure 4 is presented a vertical tubular bioreactor *(M. Farieda. s.a.. 2017.)*

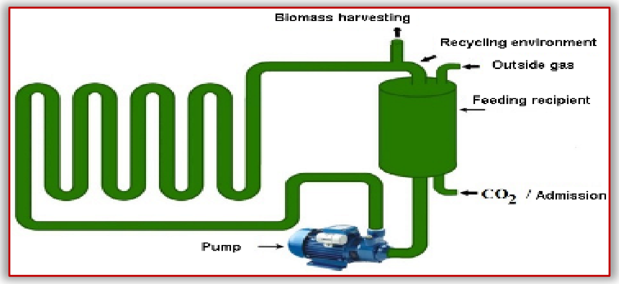


Figure 4 - Tubular photobioreactor with vertical tubes

The French-Dutch Company *Cloud Collective* (*Beverley Mitchell, 2014*) has transformed one strip of a Swiss highway in Geneva into an urban algae culture farm using the algal bioreactor with transparent pipes. (Figure5 a).

The installation was designed and manufactured in order to demonstrate that any urban scenery can be used as support for producing biomass. (Figure 5b). The algae liquid slurry circulates through the transparent pipes feeding with carbon dioxide coming from emissions generated by motorcars passing on the highway.

The process results in biomass-green fuel and environment air filtration using a simple method.

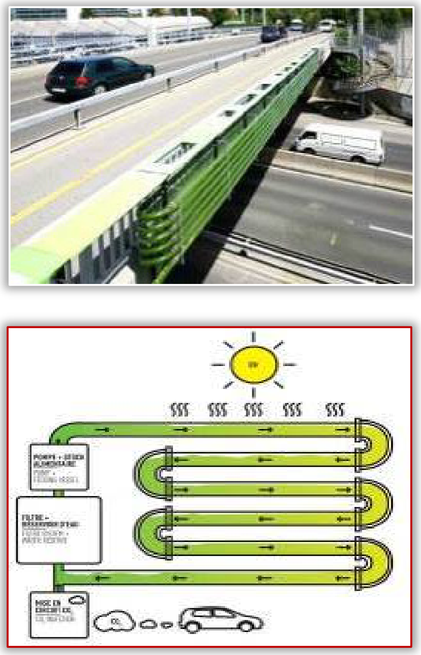


Figure 5 – Biomass production through a system of transparent pipes mounted on a viaduct
a) Highway overpass in Geneva; b) Production of algae biomass in transparent tubing reactors installed in urban areas

Another type of photobioreactor is the flat panel bioreactor as in Figure 6 (*M. Farieda s.a.. 2017. A.C. Apel s.a .2017*) The method consists in passing a thin algae layer on a transparent panel made of glass, plexiglass or polycarbonate. A special attention was given to flat photobioreactors due to big ratio between surface-volume and high density of cells.

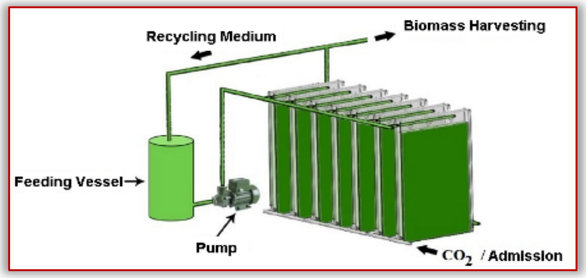


Figure 6 – Photobioreactor with flat vertical panels

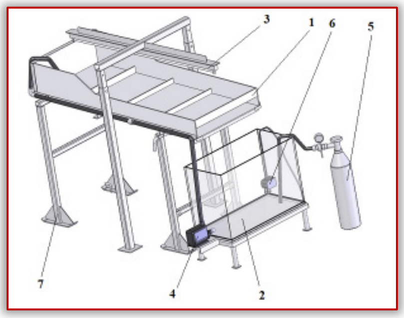
Flat panels have generally the advantage of being able to be placed vertically or inclined towards sunlight, for a better illumination.

As a general rule, the algaculture installations of any type comprise: photobioreactors, energy sources, feeding systems, stirring systems, illuminating systems, harvesting systems, automating and control systems of working process.

RESULTS

In order to study an innovative technology for obtaining algal biomass in laboratory conditions, a functional model of installation for growing algae in open system of waterfall type, has been performed within INMA Bucharest.

Installation is made of one or several flat open reactors working in waterfall system, one collecting compartment, illuminating system, stirring system, algae recirculation system, as it is presented in Figure 7.



a)

b)

Figure 7 - Installation for open system growth of algae of waterfall type - ICA: 1. flat reactor; 2. collector; 3. illuminating system; 4. recirculation system; 5. CO_2 feeding and Ph control system; 6 agitators. a) appliance diagram; b) functional model ICA

In this type of reactor, the transparent panels made of glass, plexiglass or polycarbonate enable the sun direct radiation, light dissipation of heat, easy cleaning and maintenance. Algae culture is recirculated and slips on transparent panels in a thin layer of 3…35 mm.

Algae growing technology includes a series of processes, methods and techniques that must be respected and applied for obtaining algal biomass:

— Ensuring the nutritive environment;
— Algae inoculation is accomplished by special methods varying according to culture growing characteristics, level of adaptation to concrete cultivation conditions;
— Ensuring the conditions of cultivation-temperature, illumination, stirring;
— Biomass obtaining.

The researches on algaculture in the installation of waterfall type are being in course of developing.

A microalga cultivated in this installation is Chlorella. This microalgae is rich in proteins and essential fatty acids, minerals, vitamins, fibres. Chlorella is the richest source of chlorophyll known up to present, but it is cultivated also as a rich source of ribonucleic (RNA) and deoxyribonucleic acid (DRA).

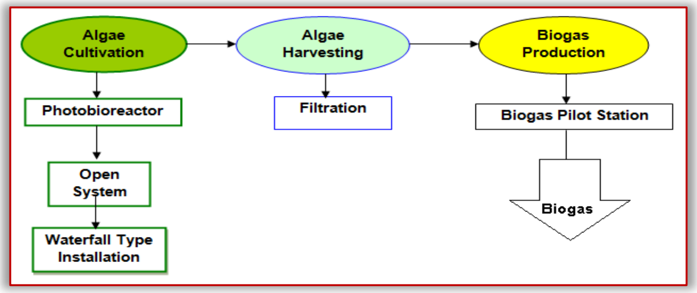


Figure 8 - Diagram-technology for obtaining biogas from algal biomass

Chlorella needs a specific medium of growing, namely a high purity and quality of water at which adds a great variety of natural minerals.

Culture of algae studied will grow in BBM (Bold Basal Medium) medium.

The innovative technology designed to obtain advanced biofuel from algae, proposed by INMA. Figure 8 consists in the following special technical equipment:

— Open growing system of algae using the waterfall type installation whose size is in accordance with the capacity of production desired.
— Algae harvesting-by filtration and centrifugal force.
— Obtaining biogas with pilot station by advanced dry and humid methanogenesis MGA endowed by INMA.

CONCLUSIONS

— In order to improve the environment quality one of the possible sources is to use the alternative energy.
— Unlike other alternative sources of energy, algae present a series of important advantages; they grow rapidly, do not compete with food sources for agricultural fields and do not need fresh water to develop.

- Microscopic algae could represent the newest and most viable and profitable generation of biofuels, outrunning the traditional fuels, natural oils and wood.
- Microalgae are microscopic aquatic organisms that feed by photosynthesis.
- In order to cultivate algae at industrial scale for obtaining biomass, three systems are viable: open, closed and hybrid systems, characterized by specific technologies and installations.
- Installation for algae growing in open system, of waterfall type can be appropriately sized according to production expected and is designed both to grow algae at lab-scale and industrial scale.
- Installation proposed is mainly made of one or several flat open reactors on which the algae culture slips in a thin layer, enabling the direct sunlight, light dissipation of heat, easy cleaning and maintenance. The advantage of system above is that to reach a high biomass density and a big productivity due to big ratio between surface and volume.
- Biomass will be capitalized through the pilot station for biogas production endowed by INMA.

Acknowledgement

The research work was funded by the NUCLEU Programme of the Ministry of Research and Innovation through financing contract no. 8 N / 09.03.2016 –Act.Ad.2/2017 for the project " *PN 16 24 04 04 „Researches regarding the development of an innovative technology for obtaining advanced biofuels from non-food bioresources.*

Note

This paper is based on the paper presented at ISB-INMA TEH' 2017 International Symposium (Agricultural and Mechanical Engineering), organized by University "POLITEHNICA" of Bucharest – Faculty of Biotechnical Systems Engineering, National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, Scientific Research and Technological Development in Plant Protection Institute (ICDPP), National Institute for Research and Development for Industrial Ecology – INCD ECOIND, Research and Development Institute for Processing and Marketing of the Horticultural Products "HORTING" and Hydraulics, Pneumatics Research Institute INOE 2000 IHP, University of Agronomic Sciences and Veterinary Medicine of Bucharest (UASVMB) – Faculty of Horticulture and Romanian Society of Horticulture (SRH), in Bucharest, ROMANIA, between 26 – 28 October, 2017.

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ISSN: 2067-3809