The use of geothermal water in the cultivation of some algae species: a review

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Abstract. Green algae have been and are being studied because of their commercial importance as a source of essential amino acids, vitamins, fatty acids and proteins. Most cultural systems today are open ponds. In Europe, Poland has beneficial conditions for broad geothermal use, with one of the renewable and sustainable energy sources. Romania has a remarkable potential in terms of geothermal energy, being considered, after Greece and Italy, as having great opportunities to use geothermal resources. Only one city in the country, city of Beius, relies entirely on this type of heating energy for homes and has important projects to become a true geothermal ecological center. In the present study, geothermal water could be used to prepare the microalgal culture surrounding to heat greenhouses used to grow algae, and to dry the biomass obtained. The use of geothermal water offers the possibility of producing algae in open ponds covered with greenhouses and plant cultivation in winter. The obtained algae can be used for the production of bio-products, biogas, algae biodiesel, with potential for application in plant cultivation.
Key Words: green algae, geothermal energy, geothermal water, sustainability.

Introduction. Geothermal energy is used on a commercial scale since 1920, when the heat of geothermal waters or the ones from geysers, has been started to be used for heating up homes as a regenerative and ecological source of energy. These types of energy, in comparison of fossil fuels, have less impact on the environment. Green alga is used by humans for thousands of years (Milledge et al 2011). It was used by the Mexican and African people (Piñero Estrada et al 2001; Milledge et al 2011) as a nutritional supplement (Huang et al 2007). Microalgae are cultivated in multiple countries in the entire world as a healthy food source (Milledge et al 2011). Although, there are over thousands or even millions of microalgae species existing in nature (Hannon et al 2010), only a few of them have been successfully produced commercially for the production of high value products (Saha & Murray 2018; Khan et al 2018; Indrayani et al 2018). They are the richest natural source of multiple components such as 70% protein, minerals, fat acids (γ-linoleic acid) (Belay et al 1993), polysaccharide (Piñero Estrada et al 2001), pigments (chlorophyll, carotenoid, important vitamins (A, B1, B2, B6, B12, C, E, biotin, folic acid) (Spolaore et al 2006). Environmental factors have impact on productivity or on the chemical components of these algae that are cultivated in a synthetical environment (Olguin et al 2001). The growing interest in these microalgae is due to its therapeutic properties of bioactive components (Piñero Estrada et al 2011) (Figure 1). Basic preparations from microalgae are used in treating different illnesses (Piñero Estrada et al 2011; Belay et al 1993) such as anemia, cancer (Selmi et al 2011), diabetes (Layam & Reddy 2006), allergies (Cingi et al 2008), anti-hipercolesterolemia (Colla et al 2008). Also they indicated radio protective (Verma et al 2006) and hepato protective effects (Ferreira-Hermosillo et al 2010), helps the immune system (Hirahashi et al 2002) and the recovery of the DNA (Grawish 2008). Toxicology studies show that these microorganisms are safe for humans. They are sold in the form of tablets or drinks for more than 20 years (Hirahashi et al 2002). These algae could be the next alternative form of food (Abd El-Baky et al 2008). Beside the beneficial effect on the human health, algae can also be used for treating industrial waste waters which are filled with heavy metals to reduce them. This technology approaches a system to treat waste waters which contain a great amount of heavy metals. This system with the help of green algae it is a much cheaper technology, low costs and easy maintenance, with minimal operational requirements.

The absorption of heavy metals by the green algae depends on the biomass concentration, intial heavy metal concentration, pH, temperature and light intensity.

Knowing these parameters, the duration of contact necessary and the intial biomass for treating waste waters can be calculated. The laboratory experiment results show that costs and water treatment times could be considerably reduced with growing and use of algae (De-Bashan & Bashan 2010).

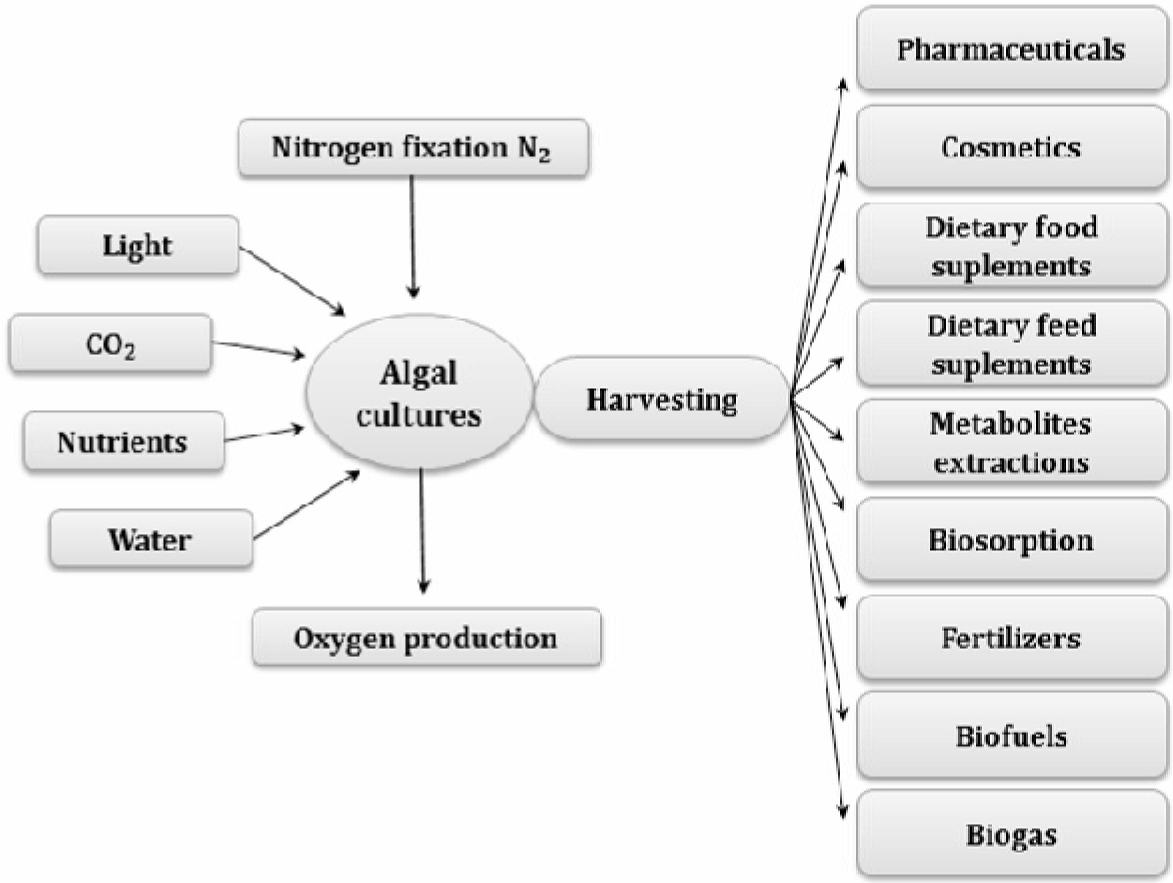

Figure 1. A schematic presentation of algal biomass production (inputs and potential outputs) (Vonshak et al 1997).

Growing green algae. During 2nd World War, Germany was the first country where green algae was used as biomass for producing useful products (Milledge et al 2011), e.g. producing fats for using energy from burning gas, biochemical, anti-microbes or treating waste waters (Grobbelaar et al 2012). Growing green algae is a big interest due to its properties (Converti et al 2006). Currently microalgae biomass production reaches 5 000 tons of dry matter per year, especially in open ponds. It means approximately 1, 25 x 109 USD/y as turnover (Spolaore et al 2006; Posten 2009). Locked bioreactors produce only a few hundred tons of biomass. In the last several years, it was noticed the growing interest of biomass use for creating biofuel with lesser costs.

The efficiency of microalgae cultures, in open air and ponds depends on a series of factors such as, temperature, nutrients, O_2, CO_2, physical factors (light quantity and quality), biotic factors, depth, dilution rate, harvesting frequency) (Andrade & Costa 2008; Moheimani & Borowitzka 2007), pH, alkaline and a high concentration of salts (Costa et al 2002).

The optimization of the parameters that affects light quantity received by the cells are: depth of the ponds, cell density, dilution cycle and turbulence, allows a better use of solar light, which results better productivity. This process can be used in bigger areas and ponds, where all these parameters can be modified (Moheimani & Borowitzka 2007).

Place of disposition and climatic conditions. Bioreactors are frequently used for commercial grow of algae, because of its simplicity, the possibility of having a better control of gas transfer, the parameters that affects directly and the light intensity. Delimiting areas is a good approach, one lighter and the other darker. In open space cultures, light intensity varies in large scales, from minimum in the early hours of the daylight, to a maximum until noon, especially in summer time (Ruiz-Marin et al 2010). In the morning, the cultures are limited to low intensity and a constant temperature, and this technology would be ideal in the tropical and semitropical areas. Although, it can be used in the temperate zone as well, such as Romania. For using this kind of technology in Romania, the place of disposition of the ponds would be ideal in geothermal zones (Figure 2) for maintaining a constant temperature with the help of this source of energy. It is known one city in the country which leans entirely on geothermal energy for heating up homes and has important projects on becoming a real geothermic and ecologic center.

Figure 2. Geothermal resources of Romania.

Other different parameters which can be used for the disposition of the station: evaporation, major problem in the tropical dry zones. Evaporation rate tends to increase the salt concentration in waste waters, which results in water rate loss (Ruiz-Marin et al 2010); optimal humidity (Samori 2012); the station has to be placed near an industrial zone, avoiding the long transportation of the effluences (Ruiz-Marin et al 2010). The growing place used for incubating the algae is full of standard nutrients which contains a large variety of inorganic nutrients, assuring the natural conditions for the growing of the organism.

Designing the station. The components of the station include the bioreactor, compressor and the agitator. The reactor has to be isolated for temperature consistency during the entire process. Every sensor that controls the temperature, pH, pressure and dissolved oxygen are installed in the bioreactor. A rotor tube animated by and engine, is installed in the reactor for mixing up the cultures and maintaining its homogenous state. Compressed air is going through a filter and inserted in the bottom of the reactor. The bioreactor has to be equipped with air outputs, a pressure reduction safety valve, protecting from other microorganisms and contamination. For cost efficiency of its design, starting point would be the size of the bioreactor for growing these algae. The main purpose is to optimize the costs for the treatment. The total costs include equipment capital and functioning and maintenance costs as well. The Raceway pool, it is a large open pool and inside of it the algae and waste water are stirred by an engine operated spatula. Its depth is 20 cm, equivalent of 200.000 liters volume. The pool is 15x74 meters, plastic material, padded with a central wooden separator. Usually, open pools register a total 6.2 mm water loss per day, due to the evaporation rate. For overcoming losses, the pools have to be covered up with a circular structure that can prevent water losses (Ruiz-Marin et al 2010).

The sensor equipment is installed in the interior of the pool and it is monitoring the conductivity, pH, algae density, temperature, dissolved oxygen and carbon dioxide. Biosensors are as well installed for detecting nitrate, phosphate, and heavy metal concentrations in the waste waters. This content of the pool is constantly mixed by a rotor for keeping the cells in suspension state, and a good contact between the algae and the waste water. Carbon dioxide is infused constantly as well in the pool. CO_2 it is injected in form of fine bubbles through pipes that are on the bottom of the pool, so the CO_2 it is dispersed uniformly. Finally a microfiltration process is taken place, followed by a centrifugation for making possible the draining and harvesting of the clear waters. (Ruiz-Marin et al 2010).

Table 1

Advantages and disadvantages of various culture systems for algae

Type of cultivation system	*Advantages*	*Disadvantages*
Open ponds (e.g., raceway ponds)	- appropriate illumination (10-50 cm deep) low-energy-consuming paddle wheels for gas/liquid mixing and circulation; - the culture medium is directly exposed to the atmosphere; - allowing liquid evaporation (regulate the temperature of the process); - made of less expensive materials; - construction involves lower costs; - requires less energy for mixing; - better turbulent flow; - shallower culture depth.	- limited to the type of microalgae that can be used for cultivation; - larger area required; - the lower efficiency of light utilization; - the poor gas/liquid mass transfer; - the lack of temperature control; - the high risk of culture contamination; - the low final density of microalgae; - significant evaporative losses; - CO_2 used not efficiently; - biomass productivity is lower than in closed cultivation systems (Borowitzka 1999; Ugwu et al 2008; Christenson & Sims 2011).
Flat-plate bioreactor	- large illumination surface area; - suitable for outdoor cultures; - good for immobilization of algae; - good light path; - high productivity; - relatively cheap; - easy to clean up; - readily tempered; - low accumulation of dissolved oxygen; - easily built; - provision of an open gas transfer unit.	- scale-up requires many compartments and support materials - difficulty in controlling culture temperature; - possibility of hydrodynamic stress to some algal strains; - algal wall adhesion; - systems are not amenable to sterilize; - incompatible with the shelf industrial fermentation equipment; (Borowitzka 1999; Ugwu et al 2008; Christenson & Sims 2011; Xu et al 2009).

Vertical-column bioreactor	- high mass transfer; - good mixing with low shear stress - low energy consumption; - high potential for scalability; - easy to sterilize; - readily tempered; - good for immobilization of algae; - reduced photoinhibition and photo-oxidation; - simple cultivation; - no moving parts; - good solid suspension; - homogenous shear; - less land is required.	- small illumination surface area; - construction requires sophisticated materials; - shear stress to algal cultures; - decrease of illumination surface area upon scale-up; - high fragility; - low versatility of the material in stake (Ugwu et al 2008; Xu et al 2009).

Conclusions. Due to the abundance of nutrients of the biomass, using green algae in agriculture is very popular. In Romania, microalgae cultures in open systems during winter time it is not possible. The solution is geothermal waters and energy for preparing the surroundings for the microalgae, greenhouses that include the bioreactors for temperature consistency that are necessary for growing. The cultivated biomass could be used for producing bio stimuli for growing and developing plants. Using geothermal energy for growing algae during wintertime, heating the water up, the soil and the drier, and CO_2 output can increase the production of these microorganisms and reduce potential costs.

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