POTENTIAL OF MICROALGAE BIOMASS FOR BIOGAS PRODUCTION

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Abstract
This review defines the potential of microalgae being a possible future raw material used for biogas production. Comparing microalgae to the commonly used raw materials shows their great potential over the traditional crops. Before the biomass processing, there is a necessity to find adequate microalgae strain because of the strong construction of the cell wall, which is a decisive parameter regarding the efficiency of the anaerobic digestion. A lot of alternative solutions for cultivation systems of microalgae, harvesting techniques, technologies of algae biomass processing are currently under development in the world. There is a need to find a reasonable way to produce algae biomass to meet all requirements involved in the ecological and economic issues.

Keywords
anaerobic digestion; biogas; biomass; microalgae; productivity

1 INTRODUCTION

Considering current technological development of the modern world, higher operation and exploitation of new unconventional resources and potential reserves, it is highly unlikely that current situation of fossil fuels will be still stable. It is a question of time when fossil fuels will not continue to be accessible at low cost [1]. That is the main reason to find an alternative resource to replace the position of fossil fuels in the world. Because of the increasing greenhouse gas emissions, rising prices for oil and petroleum, diminishing fossil fuel resources, causing a lack of energy security, increase in demand for transport fuels and global warming, the recent scientific interests have focused on the search of alternatives and sustainable renewable energy from microalgae [2]. Algae are an alternative feedstock for biofuels and bioenergy due to their high photosynthetic efficiency and rapid growth. Green algae are able to interact together with the wastewater treatment, can be grown in places and areas with infertile land. Algae biomass is becoming one of the most promising energy source of the future. The cultivation of microalgae can be performed in a photo bioreactors, raceways or in greenhouses. This new innovative process can give a prerequisite scale for increasing commercial use of bioenergy from microalgae.

2 BIOMASS PRODUCTION FROM MICROALGAE

Along with the cyanobacteria, microalgae as primitive plants are the simplest uncomplicated autotrophic organisms (mostly microscopic) with an undemanding requirements for growing and an increasing rate of growth in accordance with environmental conditions in a bioreactor. The key factors for the control of algae growth are: water, light, CO_2, optimal temperature and the N:P:K ratio. For the purpose of monitoring and optimisation of the algae growth, it can be observed a much higher productivity when compared to conventional agricultural crops. During the most important phase of algal growth - exponential phase, it can be examined the doubling of biomass in a time less than 3.5 hours. Microscopic algae can fix and use waste CO_2 (1 kg dry of algal biomass utilises about 1.83 kg CO_2) [3]. Microalgae can be considered as a suitable substrate for anaerobic digestion because of the high biomass production, low ash content and a reduced need for arable land. The selection of the optimal algae strains leads to more rapid conversion of biomass to methane. When selecting the microalgae strains, one of the most important parameters is the characteristic construction of the cell wall of microalgae, which decides about the effectiveness of the anaerobic process. Some algal strains do not have a cell wall, some of microalgae have got a cell wall made from protein without cellulose or the hemicellulose, and these parameters play a crucial role in the easier degradability. With the proper selection of microalgae strains for anaerobic digestion have to be taken into account also the other parameters such as productivity and sensitivity to contamination. If the selected strains of microalgae have a strong cell wall and are resistant to the anaerobic digestion process, there is a need to process them before using as a raw material in biogas plant.

Considering the high photosynthetic efficiency and intensive growth related to the microalgae cultivation, green algae are being studied as promising raw material for the production of fuels and chemicals. Cultivation of algae biomass for biofuel production increased at the level of interesting biomaterial for researchers from all over the world [4].

The successful cultivation of microalgae requires the knowledge of the algal ecology to ensure the precise terms of growth. It was estimated [5] that the amount of dry matter production of microalgae in the world is equal to the value of 15 000 t/y. The biomass of the microalgae is collected not only from the natural environment (water), but also from the artificial cultivation devices (raceway), or a photo bioreactor.

3 MATERIALS AND METHODS

One of the most important factors for the overall success of the algae usage is the selection of the appropriate and best performing algae strain [6]. The basic requirements for the cultivation of microalgae are as follows:

- Light exposure – one of the most essential parameters, the culture density is limited due to the availability of light, it is inversely proportional to the distance through which the light has to pass by;
- Temperature and pH control - for each species of algae there is an optimal temperature and pH range;
- Elimination of oxygen – microalgae produce oxygen proportionally to their growth (should be removed, due to toxicity);
- Supply of CO_2 - the efficient capture of carbon dioxide is an important part of system design on algae growth;
- Circulation of the culture - affects the elimination of oxygen, distribution of light, reduction of the organic matter.

The algal culture media has to provide the most essential inorganic elements, which are components of algal cells. The crucial elements contain nitrogen (N), phosphorus (P), potassium (K) and iron (Fe). The estimation of the minimal nutritional requirements can be calculated using the molecular formula specified for microalgal biomass: $CO_{0.48}H_{1.83}N_{0.11}P_{0.01}$ [7].

Biotechnological process of biomass obtaining (Fig. 2) was carried out with the use of the green algae strain *Chlorella sorokiniana* cultivating on culture medium containing the source of N, P, K in the 1000 L bioreactor with the maintaining of the optimum temperature of 25°C (strongly influences cellular chemical composition). The proper pH level was kept between 7.0 and 7.3. The algae suspension was circulated in the bioreactor to let to access the light for each algae cell. The circulation (CO_2 input) helped in elimination of oxygen, which becomes toxic in a high concentration. The light exposure (ratio) required for the adequate photosynthetic activity was kept at 16:8 (light: dark).

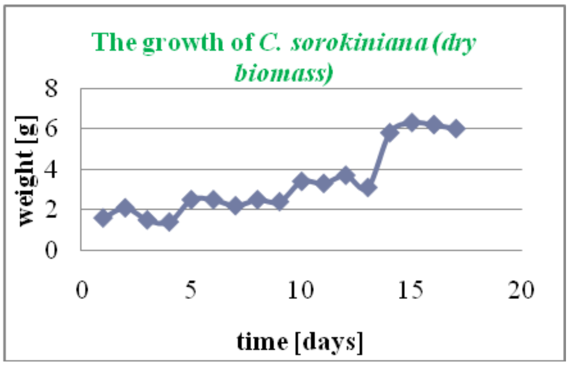

Fig. 1 The growth of *Chlorella sorokiniana* during the exponential phase of growth

Microalgae can be a perfect solution to utilise the agricultural waste and convert it into energy. One of the denouement to utilise the agricultural waste and by-products from biogas plant is the production and cultivation of green algae, which after growing based on the by-products from biogas plant can be in turn used as a feedstock in the process of anaerobic digestion. Such reuse of technological waste forms a perfect opportunity to integrate the energy producing/consuming technologies of processing of by-products and waste. However, the barrier which can be met under the development of the algae biomass production technology, becoming a large-scale business still needs to be taken into consideration [8].

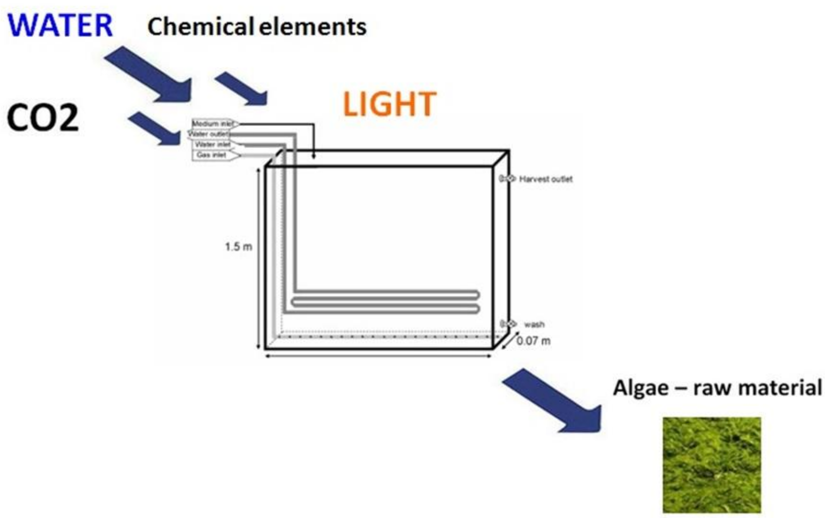

Fig. 2 The scheme of production and cultivation of *Chlorella sorokiniana*

4 RESULTS AND DISCUSSION

Based on the search for the possible alternative input materials for biogas production, the microalgae biomass of *Chlorella sorokiniana* was chosen to be used as a potential substrate. The amount of used harvested biomass was equal to 800 g (Fig. 3). The 100 L fermenter was filled with inoculum taken from the biogas fermenter in a volume of 99 L and subsequently the microalgae biomass was added (Fig. 4). After closing of the fermenter, the automatic regime of the heat control was set to heating at 40°C±1°C, as well as the automatic regime of recording a cumulative production of biogas in the gas meter control. The value of biogas production was recorded every hour. Processed outputs of the monitored parameters are given in the following tables and graphs. The cumulative biogas production is shown in the Figure 5. In total the substrate in the fermenter produced 50.9 L of biogas during 30 days, while the contribution to the biogas production was 99 L and the separated inoculum was 15.7 L. The composition of biogas is shown in the Figure 6.

Fig. 3 Sample (material) - dried microalgae

Fig. 4 The substrate filled with the microalgae in the fermenter

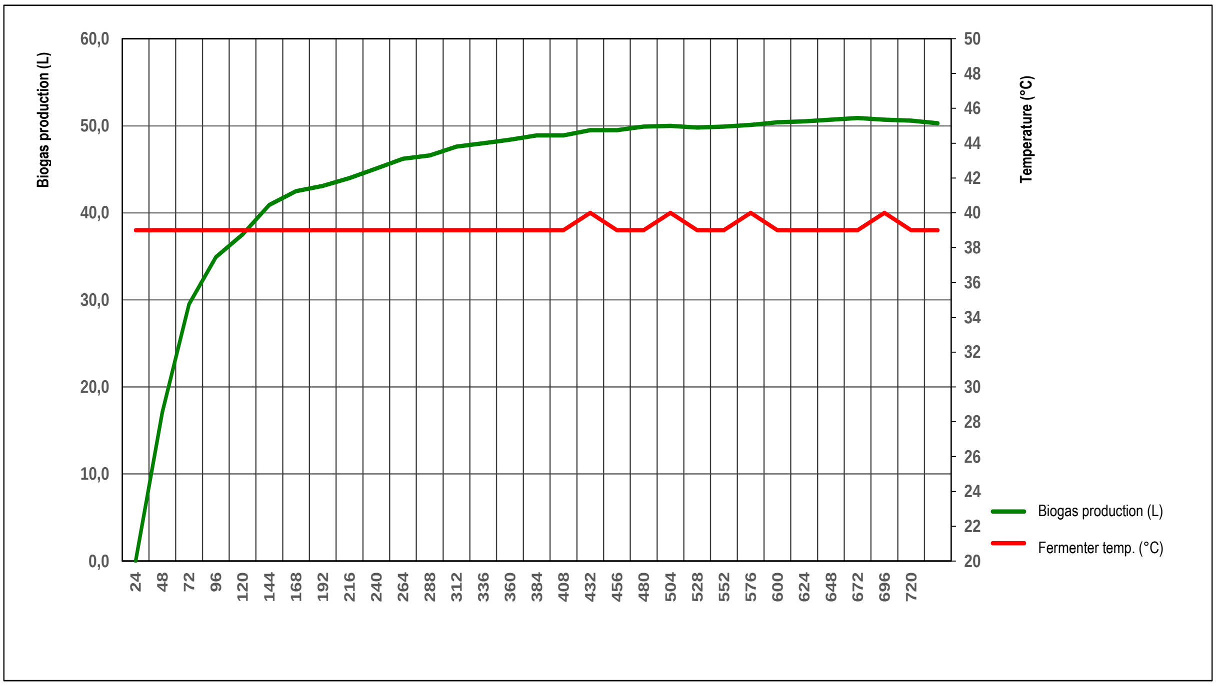

Fig. 5 Cumulative production of biogas and the course of the temperature in the fermenter

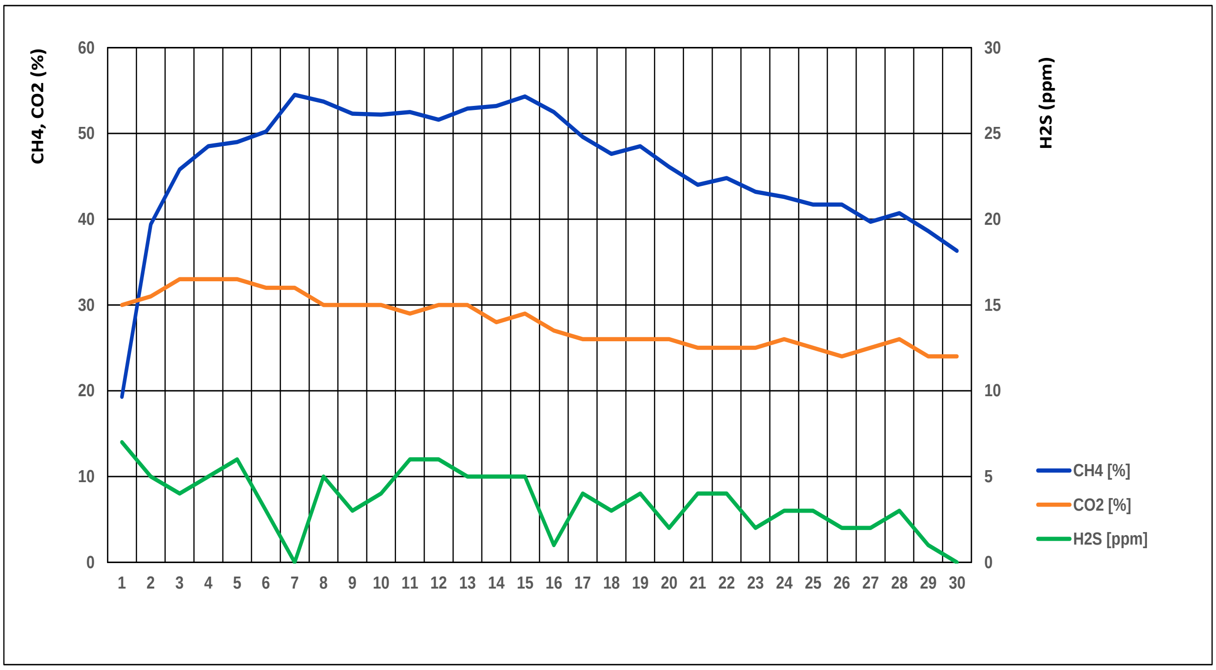

Fig. 6 The course of methane, carbon dioxide and hydrogen sulphide content in the biogas

5 CONCLUSION

The experiment has confirmed that the microalgae biomass of *Chlorella sorokiniana* is possible to use for the biogas production with the method of wet fermentation. The achieved methane content in the biogas was 59.41% (by volume) and the low level of hydrogen sulphide in the value of 3.56 ppm. Thus, the biogas does not require the time of use in desulfurization cogeneration unit (for the value to less than 100 ppm). During the 30 days of experiment in the 100 L fermenter, the total biogas production was equal to the value of 50.9 L, representing an average daily production of 1.69 L. By the conversion of the biomass to the value of dry matter (TS %) of microalgae, giving a value of 92.69 %, the dosage of the dry matter (TS) and organic dry matter (VS) of the microalgae was as follows:

TS = 0,742 kg of substrate

VS = 0,391 kg of substrate

The average overall production of biogas (BP) on the unit of dry matter of the substrate is:

BP production = 0.0685 m^3/ kg (TS)

BP production = 0.13 m^3/ kg (VS)

For comparison, the results obtained from the same experiment with the use of 97 L of manure (composition: 80% of pig manure, 20% of cattle manure). The results are shown in the Table 1. The total production of biogas reached 106.80 L, by the calculation for the unit of the dry matter of used input material (dry matter content of manure was TS = 3.31 %) was reached the production of biogas with the methane content of 52.56%.

Development among the installations of biogas plant in the European Union is a constantly increasing trend. It is therefore necessary to search for a suitable replacement for the prime maize silage. As shown in the experiment, the promising alternative can be microalgae biomass.

Substrate (input)	Total biogas production [L]	Average dose of substrate [kg]	Average biogas production per unit of TS [m3/kg]	Average methane content [%]	Average carbon dioxide content [%]	Average hydrogen sulphide content (ppm)
Microalgae 0,8 kg + 99 L of inoculum	**50,9**	**0,742**	**0,0685**	**46,23**	**28,0**	**3,56**
Manure 97 L	**106,8**	**3,211**	**0,0333**	**52,56**	**36,33**	**343,6**

Tab. 1 Average calculated value of biogas production and biogas composition

6 ACKNOWLEDGEMENT

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