The use of solar light for green algae cultivation and liquid digestate treatment

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Introduction

Digestate is a complex semi-liquid waste generated during anaerobic digestion. Most often, it is separated into a solid and a liquid fraction, which allows to treat them independently. The liquid fraction is definitely more difficult to treat, manage and creates more environmental problems than the solid digestate. This is mainly due to a low C/N ratio and a high content of refractory substances, including phosphorus, nitrogen and heavy metals (Koutra et al., 2018). Additionally, a high content of water in the liquid digestate limits its direct utilization as fertilizer or soil conditioner due to the costs of such management. So far, several techniques have been developed to treat the liquid digestate, including: electrocoagulation, ammonia desorption, or struvite precipitation (Gienau et al., 2020; Szymanska et al., 2019). However, these methods are characterized by low efficiencies at high costs and often generate byproducts difficult to treat. One of the new promising approach is the application of microalgae, which are capable of utilizing recalcitrant pollutants present in the digestate. Specifically, microalgae mainly use ammonium nitrogen, nitrates, phosphates as well as some organic compounds to transform them into cellular substances via photosynthesis (Christenson and Sims, 2011). Liquid digestate containing the listed components is therefore a potentially attractive material for the cultivation of microalgae. As a result, this fraction can be reused in a biogas plant (e.g., for diluting raw waste), which is in line with the idea of circular economy. In countries with a transitional climate, such as Poland, cool and cloudy months prevail, and cultivation of algae requires artificial lighting. However, during the summer months, the cultivation systems can be exposed to natural sunlight, which would reduce the operating costs and possibly enhance the growth of algae. Hence, in this research, a consortium of microalgae from the earlier study (Sobolewska et al., 2022) was applied for the treatment of liquid digestate under solar lightning conditions. The main objective of the research was to recognize how the natural light affects both the removal rate of nutrients and organic contaminants from the digestate and the microbial community developed during the cultivation.

Materials and methods

Materials

The undiluted liquid digestate obtained from anaerobic digestion pilot plant treating vegetable wastes (corn with green peas) was used in the research. A consortium of two microalgae *Tetradesmus obliquus* and *Microglena* sp. was applied for cultivation.

Experiment

The experiment was carried out in a photobioreactor with a capacity of 350 mL operated semi-continuously. The reactor was illuminated by sunlight with an average intensity of 6000 Lux in the summer months (May-August). During the experiment, the natural cycles of day and night were maintained. Chemical oxygen demand (COD) and microbiological parameters defined by the number of algal cells and chlorophyll *a* concentration were measured once a week. The other indicators were determined twice a week.

Analyses

HACH-Lange tests, including PhosVer3 (no. 8048), NitraVer5, modified Nessler (no. 8038), and LCK214 were used to determine orthophosphates, nitrates V, ammonium nitrogen and COD, respectively. Additionally, turbidity and TSS were determined at 860 nm and 810 nm. Microalgae biomass was monitored by measuring the optical density at 680 nm, the level of chlorophyll *a* and the algal cell density.

At the end of the experiment, the biomass from the photobioreactor was analyzed metagenomically (V3-V4 of 16S rRNA) in order to determine bacterial community.

Results

The treatment efficiency of the photobioreactor was assessed based on the removal rate of nutrients and organic compounds under steady-state conditions. The treatment process allowed to remove up to 86% of orthophosphates from the digestate, the concentration of which was reduced to 49 mgP/L. These results are similar to the findings of (Xu et al., 2015) where *Scenedesmus obliquus* was applied for the treatment of piggery anaerobic

effluent. Furthermore, during the experimental run, above 86% of nitrogen (calculated as the sum of nitrates and ammonium nitrogen) and 91% of soluble COD were also removed from the liquid digestate, and these rates are much greater than described in the literature (Bankston and Higgins, 2020; Pizzera et al., 2019)(Pizzera et al., 2019).

The microbial analysis revealed that since the beginning of the experiment, the *Tetradesmus obliquus* algae dominated in the photobioreactor biomass, followed by *Microglena* sp. The concentration of algal biomass was gradually increasing as the process was continuing. After reaching the steady state condition, the average number of microalgae cells was 1.12×10^6 cfu/mL, while the mean chlorophyll *a* concentration reached the level of 23.0 mg/L. Considering the metagenomic analysis, it was observed that the most dominant bacteria at the phylum level were Firmicutes (26.31% relative abundance) and Patescibacteria (17.38%). Based on these findings, bacteria were mainly responsible for nitrification and oxidation of organic contaminants present in the digestate (Zhang et al., 2021).

Conclusions

The research demonstrated that microalgae could successfully be used for the treatment of the liquid digestate under natural sunlight, and as much as 90% of nutrients and organic contaminants could be removed. The use of natural sunlight during the summer months can potentially reduce the cost of liquid digestate treatment in countries with a transitional climate, such as Poland.

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