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Western waterweed (*Elodea nuttallii*) as a co-substrate for biogas plants

Western waterweed (***Elodea nuttallii***) grows vigorously in bodies of water in Germany and hinders in many places their recreational use. For this reason, this aquatic plant is now often harvested and subsequently disposed of as organic waste. As a possible alternative use, the harvested ***Elodea*** biomass can also be used as co-substrate in biogas plants. As the digestion of western waterweed alone in a laboratory biogas plant led to a reduction of the biogas yield of over 50 %, ***Elodea*** was used in combination with maize silage. A mix of 30 % *Elodea* and 70 % maize silage produced a biogas yield of 580 standard litres per kilogram of organic dry matter. In addition, the aquatic plant and maize were readily ensilable, which made it easy to store and ensured that it was ready to use over a longer period of time.

Keywords
Waterweed, biogas, substrate

Abstract
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The American or Canadian waterweed (*Elodea canadensis*) was introduced to Europe back in 1836 and is familiar as a popular aquarium plant, while its relative, the Western waterweed (Elodea nuttallii) remains largely unknown. Both plants originate from North America [1]. They can now also be found in waters in Europe and are characterized by their ability to grow very quickly [2]. Up to now, *Elodea nuttallii* has mainly been concentrated in western parts of Germany, although it can increasingly be found in the east of the country too [3]. *Elodea* nuttallii, which will be referred to hereunder simply as *Elodea*, is also becoming important from an economic viewpoint as it can be found in more and more lakes and often effectively chokes these lakes. Aquatic organisms prosper in dense growths of *Elodea*, and herbivorous water birds such as mute swans and bald coots benefit from the plentiful supply of food. However, lakes with major growths of *Elodea* can be used for bathing and other sports activities such as sailing regattas, rowing and surfing only if the plant growth is removed beforehand (**figure 1**).

Harvesting is the only practical option

As the use of herbicides in waters is forbidden in Germany and herbivores present in nature such as fish, crustaceans and water birds reduce growths of *Elodea* only to a small extent and in an uncontrolled manner, the only effective method of removing this plant is to cut it down using special harvesting boats. With this method, *Elodea* is first harvested in the water and then transported to dry land. Research divers have measured *Elodea* densities per unit area of up to 17 kg/m² (fresh weight) in the 'Goitzschesee' lake in the state of Saxony-Anhalt, Germany [4]. This post-mining lake has an area of 13.3 km² and a water volume of 216 million m³, making it one of the biggest water bodies in Germany. *Elodea* has been cut down to a water depth of around 5 m here close to the lake shore to allow for bathing and for boats to be able to operate. *Elodea* can dominate the entire water surface in more shallow waters such as the reservoirs along the Ruhr river (**figure 1**). The *Elodea* biomass harvested in this way contains 80 % to 90 % water and is generally disposed of as organic waste.

What should be done with the harvested biomass?

An end to the spread of *Elodea* nuttallii does not appear to be in sight, so it is important that a use for this biomass be found. *Elodea* can only be composted by adding material such as shredded wood that will add structure and thus ensure good aeration of the compost heap. *Elodea* can also be used as a substrate in biogas plants. Ideally, the bodies responsible for lakes would give the harvested *Elodea* biomass to a biogas plant operator

Fig. 1

Fig. 1: Elodea nuttallii in the ‘emnader lake‘ close to Bochum in October 2009

free of charge. In this way, organic waste could be used as a cost-effective substrate for biogas plants and disposal costs could be avoided. Samples from five lakes in Germany have been investigated in a discontinuous fermentation test as per VDI 4630 (**table 1**) in order to determine the extent of the variation in the fraction of *Elodea* that produces energy.

The data in **table 1** shows that the ratio of gas formation from *Elodea* to fraction of organic biomass is similar for all the lakes investigated, with an average value of 450 SL/kg_{oDM}. The average gas formation for maize silage is 650 SL/kg_{oDM} [5]. When related to fresh mass (harvested material), *Elodea* with an average of 29 SL/kg_{DM} performs significantly worse than maize silage with around 200 SL/kg_{DM}. However, the water content can be significantly reduced from initial values of up to 90% if the weather is dry by pre-wilting the *Elodea* biomass directly after harvesting.

In a pilot biogas reactor with a working volume of 40 liters, maize silage was gradually replaced by *Elodea* with the harvested moisture content, with the amount substituted depending on the organic content (o_{DM} = organic dry matter) (**figure 2**).

Adding even 5% of *Elodea* biomass with the harvested moisture content corresponds to around 6 metric tons per day for a biogas plant with an output of 500 kW. It should also be taken into account that *Elodea* contains a range of components that are beneficial for the biogas plant. For example, there may be no need to add trace elements and the process can be stabilized (**table 2**). As a consequence, there may indeed be advantages to the use of *Elodea* as a co-substrate in the operation of a biogas plant.

Can *Elodea* be preserved?

Large amounts of *Elodea* are gathered during the seasonal harvest. However, this biomass cannot be stored due to its strong tendency to decompose quickly. A smell of rotting flesh accompanies this decomposition process, and a significant reduction in the pH value (to 6.5 after 5 days) is not achieved even if air is excluded. As it is essential that biomass be available over a longer period for use in biogas plants, experiments on ensilaging have been carried out. **Table 3** shows the behavior of the pH value and the lactic acid content in a mixture of 30% *Elodea* and 70% maize that already contained a high amount of lactic acid bacteria when harvested, both without additives and with the addition of the silage inoculant BIO-SIL® (*Lactobacillus plantarum* DSM 8862 and DSM 8866). It can clearly be observed here that the lactic acid necessary for ensilaging can also be produced without the addition of a silage inoculant if maize with a high content of epiphytic lactic acid bacteria is added. The ensilaging process is largely completed after just 13 days. In the case of silage with 30 % *Elodea* and 70 % maize, the specific gas formation reached an average of 694 SL/kg_{oDM} and, with silage inoculant, 749 SL/kg_{oDM} (average values of three parallel experiments). It is known that the specific gas

Table 1

Table: 1: Analysis of Elodea samples from five lakes in Germany (n = 3)

Seen/ *Lakes*	**TS [% i. d. FM]/** *DM [% i. FM]*	**oTS [% i. d. FM]/** *oDM [% i. FM]*	**Gasbildung [L_N/kg_{oTS}]/** *Gas production [SL/kg_{oDM}]*	**Gasbildung [L_N/kg_{FM}]/** *Gas production [SL/kg_{FM}]*	**CH_4 [%]**
Baldeneysee Essen	16.67	7.18	416	29.8	63
Goitzschesee Bitterfeld	6.74	4.36	476	20.6	55
Hennetalsperre Meschede	24.98	6.32	457	28.9	62
Lordsee Osnabrück	6.33	4.82	415	20.0	64
Toeppersee Duisburg	11.64	8.54	520	44.4	58

Fig. 2

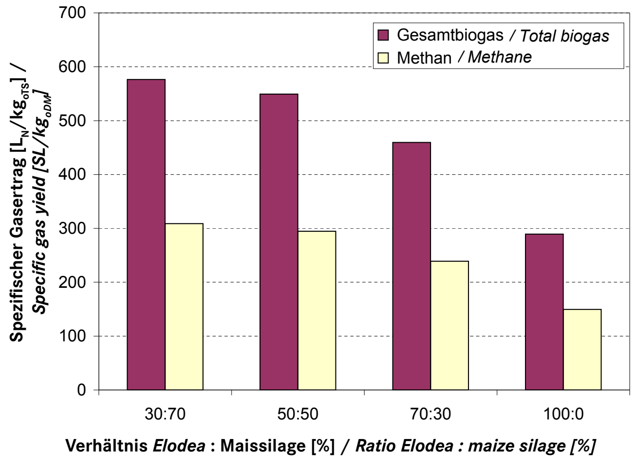

Fig. 2: Specific gas yield from Elodea-maize substrate mixtures

formation can be increased by using silage inoculants, particularly in the case of maize.

A mixture of 30% *Elodea* and 70% *Phalaris* showed significantly poorer ensilaging performance than the mixture of *Elodea* and maize. Reed canary grass (*Phalaris arundinacea L.*) was tested as a substitute for cut grass and as a possible substitute for maize. After five days, this mixture had only achieved a pH value of 4.5 and a lactic acid content of 5.2 g/kg_{oDM}.

Conclusions

Tests in actual applications will show whether the use of *Elodea* biomass in biogas plants is attractive from an economic viewpoint. The *Elodea* biomass would then at least serve a useful purpose if used as a feedstock in biogas plants. It should be noted here that *Elodea* biomass is currently classified as biomass that does not qualify for the renewable resources bonus in Germany, and thus it cannot be used as a substrate in renewable resources biogas plants without incurring financial losses. To allow for this use, this biomass would have to be included in Whitelist III of Appendix 2 of the German Renewable Energy Act. Many bodies responsible for lakes can already confirm from their many years of experience that *Elodea* grows back again and again. The only thing missing so far is the demand for *Elodea* as a resource, but this may change in the future.

Table 2

Table 2: Selected elements in Elodea samples from various lakes

Seen/ ***Lakes***	**Nickel [mg/kg_{TS}]/** ***Nickel [mg/kg_{DM}]***	**Kobalt [mg/kg_{TS}]/** ***Cobalt [mg/kg_{DM}]***	**Eisen [g/kg_{TS}]/** ***Iron [g/kg_{DM}]***	**Kalium [g/kg_{TS}]/** ***Potassium [g/kg_{DM}]***	**Magnesium [g/kg_{TS}]/** ***Magnesium [g/kg_{DM}]***
Baldeneysee Essen	23.2	4.8	2.8	14.7	2.6
Goitzschesee Bitterfeld	194	12.5	3.1	44.1	1.8
Hennetalsperre Meschede	11.6	3.7	6.9	36.1	3.3
Lordsee Osnabrück	33	9.0	3.3	46.1	1.6
Toeppersee Duisburg	3.4	0.9	6.4	30	2.9

Table 3

Table 3: Ensiling success for an Elodea-maize mixture with and without silage inoculant (n = 3)

Substrate/ ***Substrates***	**pH-Wert/** ***pH***			**Milchsäure [g/kg_{oTS}]/** ***Lactic acid [g/kg_{oDM}]***		
	5 d	***13 d***	***49 d***	***5 d***	***13 d***	**49 d**
30 % *Elodea* + 70 % Mais / *Maize*	4.13	3.91	3.77	8.9	12.0	12.5
30 % *Elodea* + 70 % Mais / *Maize* + Biosil®	4.10	3.87	3.76	9.0	11.4	13.7

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