ANAEROBIC FERMENTATION OF JERUSALEM ARTICHOKE (*HELIANTHUS TUBEROSUS*)

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Abstract: The current trend in the field of biogas is to build smaller plants than before. Linked to this is the possibility of using smaller agricultural areas in less accessible locales with low-quality soil. Agricultural biogas plants utilize mostly corn silage. For maize the specific production of biogas can be around 0.500–0.550 $m^3 \cdot kg^{-1}$ and the methane content in the material is more than 55%. In these areas, it is necessary to consider other crops, which would be suitable to worse conditions. One option is the Jerusalem artichoke, which might yield biogas in a manner comparable with maize. The average production of biogas from the Jerusalem artichoke silage was 0.437 $m^3 \cdot kg^{-1}$, the average concentration of methane was 53.00%. To compare the quantity and quality of biogas from the Jerusalem artichoke, the Nation-wide Reference Laboratory of Biogas Transformations at Mendel University has carried out anaerobic fermentation tests.

Keywords: Jerusalem artichoke, anaerobic fermentation, biogas, methane

INTRODUCTION

The Jerusalem artichoke sunflower (*Helianthus tuberosus*) is a perennial herb with a stem of 1–3 meters (Linxi et al. 2015). The underground part of the plant forms tubers. The blossom of the plant has yellow petals with a length of 5–7.5 cm, which resemble those of sunflowers. (Kasal et al. 2013) The tubers of the Jerusalem artichoke, which have been used as livestock fodder, are now being investigated as an energy source. The Jerusalem artichoke is morphologically similar to the sunflower plant. The plant is undemanding in regards to environmental conditions (Seppälä et al. 2013). It tolerates wet and dry areas, and its tubers are resistant to severe frost, making it suitable for cultivation in foothill and mountainous areas. When grown for high biomass production, it can be established and multi-cultured (Gunnarssona et al. 2014). The tubers and the green mass are possible silage material. Depending on agro-technical measures, the average yield of the tubers is 29–51 $t \cdot ha^{-1}$.

The goal of this research has been to determine whether the biogas generated during the anaerobic fermentation of this material will result in qualitative and quantitative values that are sufficient for processing in biogas plants.

MATERIALS AND METHODS

The tests, which have taken place in the Nationwide Reference Laboratory of Biogas Transformations at Mendel University were based on batch reactors with the capacity of 0.003 m^3. These reactors were filled with inoculum from the Čejč biogas station and an appropriate amount of Jerusalem artichoke material.

First, the dry matter content and the combustible substance content of the materials were determined for the individual parts of the Jerusalem artichoke and inoculum. Values are given in Table 1.

Table 1 Contents of dry matter and volatiles in the inoculum and input materials

	Dry matter content [%]	Combustible content [%]
Inoculum	3.6	60.2
Artichoke tubers	15.47	92.5
Above-ground portion of artichoke	21.7	85.4
Jerusalem artichoke silage	14.15	85.8

Each sample was then ground with a hand mixer to particle lengths of less than 0.002 m. The samples were consequently fed to the reactor. The experiment was done in triplicate. 3 reactors were supplemented with 0.040 kg of artichoke tubers, 3 reactors with 0.1 kg aboveground artichoke parts, and 3 reactors with 0.06 kg of Jerusalem artichoke silage. Each reactor received a 2 kg dose of inoculum. Two reactors were kept as a control, containing only inoculum without any test material. The volume of biogas generated by these reactors was subtracted from the volume of biogas generated by the Jerusalem Artichoke reactors in order to determine the production of biogas in the fermentation of the measured material.

Anaerobic fermentation was maintained for 23 days. Every 24 hours, the volume increase of the biogas produced by the water gasholder were recorded, as was the composition of the biogas. The methane, carbon dioxide and hydrogen sulphide contents was determined using the Dräeger X-am 7000 apparatus.

The reactors were equilibrated in water bath at 41.9°C, which is a temperature value that satisfies mesophilic methanogenic organisms (Tesařová 2010). Although this temperature leads to smaller biogas yields, the methane content of the biogas, which is the primary indicator of its quality, is higher.

Table 2 Dosing and substance load

Reactor no.	Amount of inoculate [kg]	Dry matter inoculate [%]	Dose Material [kg]	Dry matter sample [%]	Substance load [$kg \cdot kg^{-1}$]*
Artichoke tubers 1	2	3.6	0.041	15.47	0.08809
Artichoke tubers 2	2	3.6	0.041	15.47	0.08809
Artichoke tubers 3	2	3.6	0.040	15.47	0.08594
Above-ground portion of artichoke 4	2	3.6	0.102	21.7	0.30749
Above-ground portion of artichoke 5	2	3.6	0.101	21.7	0.3044
Above-ground portion of artichoke 6	2	3.6	0.101	21.7	0.3044
Jerusalem artichoke	2	3.6	0.060	14.15	0.11792

silage 7					
Jerusalem artichoke silage 8	2	3.6	0.061	14.15	0.11988
Jerusalem artichoke silage 9	2	3.6	0.060	14.15	0.11792
Inoculum 10	2	3.6	–	–	–
Inoculum 11	2	3.6	–	–	–

* Substance load indicates the amount of solid materials fed in expressed in kilograms per kilogram of dry matter of the inoculate.

RESULTS AND DISCUSSION

The average specific biogas production of artichoke tubers was 0.691 $m^3 \cdot kg^{-1}$ with an average methane content of 57.44% at a specific volume of 0.352 $m^3 \cdot kg^{-1}$. The average specific biogas production from the aerial parts of artichoke was 0.484 $m^3 \cdot kg^{-1}$; the methane content was 53.26% on average, corresponding to 0.249 $m^3 \cdot kg^{-1}$. The average production of biogas from the silage was 0.437 $m^3 \cdot kg^{-1}$, the average concentration of methane was 53.00%, corresponding to 0.218 $m^3 \cdot kg^{-1}$.

The specific productions of methane in energy maize varieties tend to be within the range 0.270–320 $m^3 \cdot kg^{-1}$ (Tesařová 2010), which is similar to that of the Jerusalem artichoke (Hutňan et al. 2009). For maize, however, the specific production of biogas can be around 0.500–0.550 $m^3 \cdot kg^{-1}$ and the methane content in the material is above 55% (Schulz, Eder 2004). Biogas with a methane content of at least 50% is, however, required for an economical operation of CHP units and also to maintain the longevity of these devices.

Figure 1 shows that for all measured samples, the volume concentration of methane peaked after about 5–6 days of anaerobic fermentation. From then on, the concentration remained essentially the same, but the overall daily production of biogas declined. The fermentation curve in the control was expected to go down, as no new material was being injected from which the microorganisms could produce more biogas.

Figure 1 Methane content in biogas

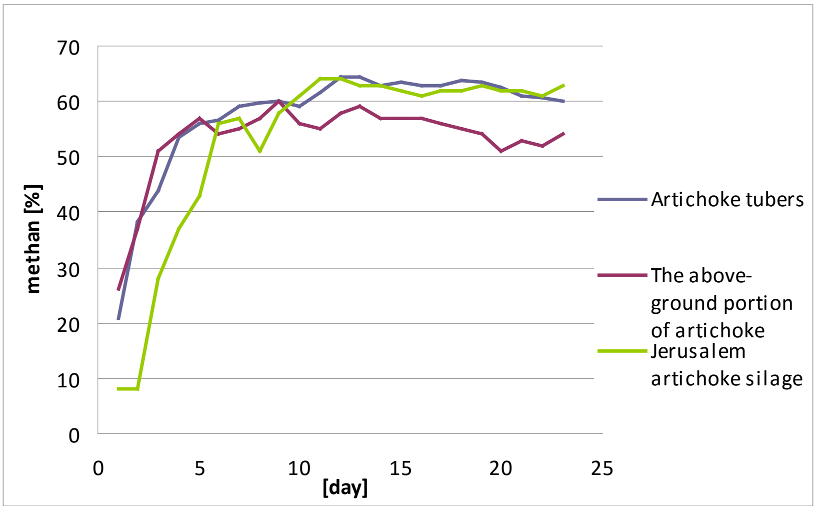


Figure 2 is used to compare the specific volume production of methane in the measured substrates. During the first 8 days, when the rate of anaerobic fermentation was the highest, the Jerusalem artichoke tuber reactors produced the highest amounts of methane at about 0.3518 $m^3 \cdot kg^{-1}$. This is due to higher contents of biodegradable substances in the reactor, which lead to multiple microorganisms with higher metabolic rates. As it can be seen, the Jerusalem artichoke silage produced the least methane at 0.2183 $m^3 \cdot kg^{-1}$, substance load 0.1179 $kg \cdot kg^{-1}$.

Figure 2 Daily specific methane production

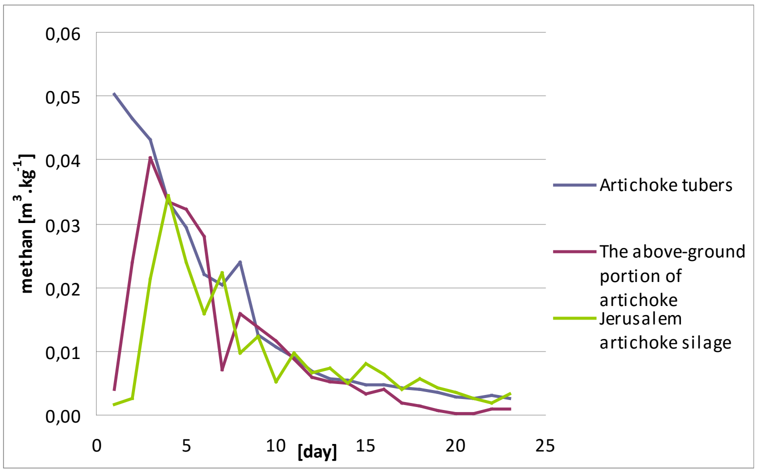


Figure 3 shows a comparison of the measured data. It is evident that the methane concentration in all samples averaged above 50%, making the biogas from these samples suitable for direct combustion. Values reached by corn silage approached the biogas and methane production of Jerusalem artichoke tubers. Silage made out of the above-ground portion of the artichoke showed a lower production rate than did corn silage or Jerusalem artichoke tubers. We can compare the entire Jerusalem artichoke plant with corn silage by using the sum of the measured values for the above-ground artichoke parts and artichoke tubers. A yield comparison with corn silage showing dry matter per hectare and methane production can be found in figure 4.

Figure 3 Representation of methane in the biogas in selected samples

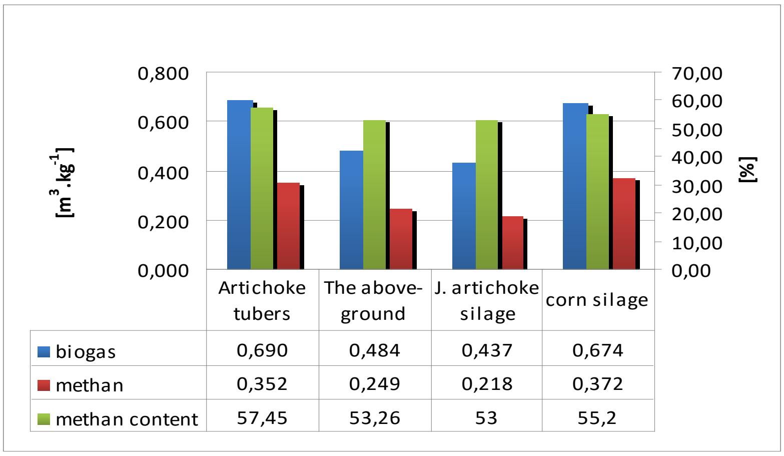
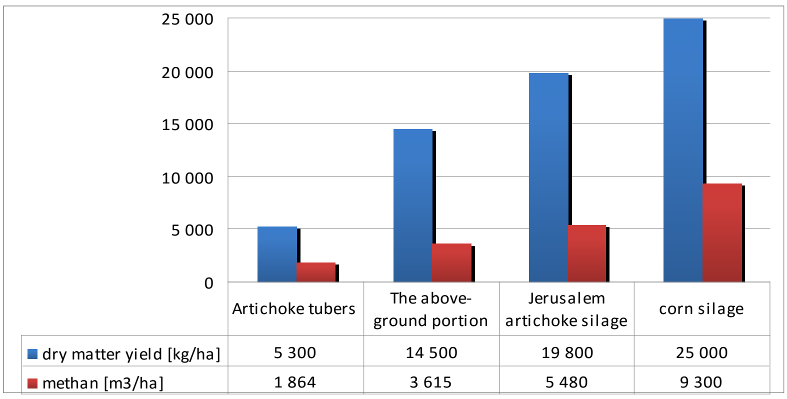


Figure 4 Comparison of dry matter per hectare yields and methane per hectare yields



CONCLUSION

This work was to evaluate the feasibility of the Jerusalem artichoke as a biogas plant material in regards to the quality and quantity of the biogas yield.

Anaerobic fermentation of the material was maintained for 23 days at 41.9°C. Each test sample was injected into three different reactors. Daily biogas yields were recorded, as was their composition. Both were compared with the production of biogas in the controls.

The average methane yield of Jerusalem artichoke tubers was 57.45%. For above-ground portions of the artichoke, the methane yeild was 53.26% and 53% for ensiled aerial Jerusalem artichoke parts. These values make the materials suitable for use in anaerobic fermentation cogeneration units that use various materials and have a methane yield of about 50%. Given the yield of dry matter of the Jerusalem artichoke, the total specific volume of methane in the biogas resulting from the anaerobic fermentation is 5.480 $m^3 \cdot kg^{-1}$. Compared to silage maize at 9.300 $m^3 \cdot kg^{-1}$, this value is lower, and that could make the economics of such operations problematic. However, we can say that the Jerusalem artichoke is suitable for use in biogas stations with cogeneration units and thus constitutes a way of utilizing poor quality soils.

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