BIOHYDROGEN PRODUCTION FROM JERUSALEM ARTICHOKE AND BAKERY WASTE DURING DARK FERMENTATION

K. Bułkowska[1], W. Gączewska[1], K. Świątek[1], T. Pokój[1], B. Dubis[2]

[1]Department of Environmental Biotechnology, Faculty of Geoengineering, University of Warmia and Mazury in Olsztyn, Olsztyn, Słoneczna 45G, 10-709, Poland

[2]Department of Agrotechnology and Agribusiness, Faculty of Agriculture and Forestry, University of Warmia and Mazury in Olsztyn, Olsztyn, Oczapowskiego 8, 10-720, Poland

INTRODUCTION

The technology of biohydrogen production from biological wastes through fermentation is less expensive, offers environmentally friendly methods in terms of energy balance, and creates an avenue for sustainable utilization of massive agricultural wastes. However, biohydrogen production is generally limited by lower productivity (Zheng *et al*., 2022). Practically, a maximum H_2 yield of 4 mol H_2/mol glucose can be achieved in dark fermentation, but theoretically a yield of 12 mol H_2/mol glucose can be achieved. This low yield in dark fermentation is mainly due to the production of other byproducts such as acetic acid, propionic acid, and butyric acid (Osman *et al*., 2020).

A variety of carbohydrate-rich substrates, such as sugar-containing plants or industrial wastewater streams, can be used for dark fermentation. Studies with lipid- or protein-rich substrates have shown that they produce very little hydrogen (Sampath *et al*., 2020).

MATERIALS AND METHODS

Substrate characteristics. Jerusalem artichoke from a farm in Tomaszkowo (Poland) and bakery waste from a local bakery (Olsztyn, Poland) were used as substrates for dark fermentation. Before the experiment, both substrates were dried at 60°C. The Jerusalem artichoke had a dry matter concentration of 92.69% and an organic compound content of 88.21%. For the bakery waste, the corresponding values were 97.61% and 94.83%. The contents of protein, crude fat and crude fiber in Jerusalem artichoke were 3.58%, 0.29% and 26.11%, and in bakery waste were 13.64%, 0.62% and 1.29%, respectively.

Experimental setup and equipment for dark fermentation. The laboratory experiments were conducted in two series. In series 1, the substrate consisted of Jerusalem artichoke and in series 2, bakery waste. Both series had constant organic loading rates of 5.15 g VS /L·d and a hydraulic retention time of 15 days. The process was run for 60 days. Dark fermentation was carried out under mesophilic conditions at 39 °C (± 0.5 °C). The series was carried out in fully mixed reactors with a working volume of 6 L (Fig. 1). The volume of substrate fed to the reactor during the day was 400 ml, which was equal to the volume of digestate removed from the reactor. The chambers were made of stainless steel and equipped with a heating jacket and a stirrer with adjustable rotation speed. Valves located at the top and bottom of the reactor allowed biogas and digestate to be fed into and removed from the chamber. The reactors were operated in a *quasi*-continuous system and fed once a day after the digestate was collected. The inoculum was obtained from the chambers for anaerobic digestion of sewage sludge from the municipal wastewater treatment plant in Olsztyn (Poland). The produced biogas was collected in Tadler bags. The volume of biogas was measured with a meter. The composition of the biogas in terms of maximum hydrogen and carbon dioxide content and minimum oxygen content was determined by gas chromatography.

GOAL

The aim of this study was to investigate Jerusalem artichoke and bakery waste during dark fermentation.

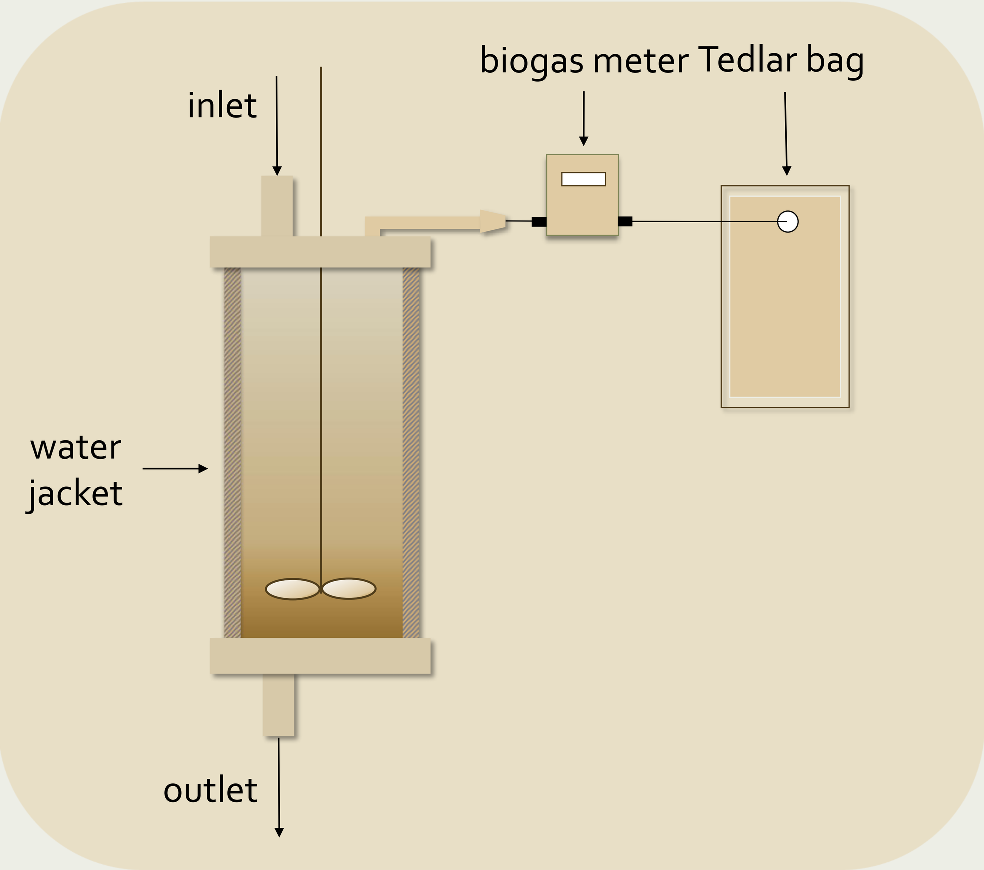

Fig. 1. The scheme of the anaerobic digester.

RESULTS

Biogas/hydrogen production during dark fermentation of Jerusalem artichoke and bakery waste. Bakery waste is a more effective substrate for hydrogen production compared to Jerusalem artichoke. Under the same operating conditions, cumulative biogas production in the series with bakery waste (364 L) was 4.4 times higher than with Jerusalem artichoke (82.9 L) (Fig. 2a). The biogas production rate was also 4.2 times higher with bakery waste than with Jerusalem artichoke (Fig. 1b). The hydrogen production rate was higher in bakery waste and was 0.66 L/L·d. compared to Jerusalem artichoke, where the biogas production rate was 0.05 L/L·d. (Fig. 2b).

Figure 3a shows the changes in pH in both series. At the beginning of the process, the pH values in the series with Jerusalem artichoke decreased from 7.3 to 5.43 and with bakery waste to 4.72 (the first 10 days of the experiment). After that, the pH stabilized and averaged 5.40 and 5.01 in the series with Jerusalem artichoke and bakery waste, respectively. The concentration of volatile fatty acids was 1.87 times higher during the dark fermentation of bakery waste than with Jerusalem artichoke (Fig. 3b).

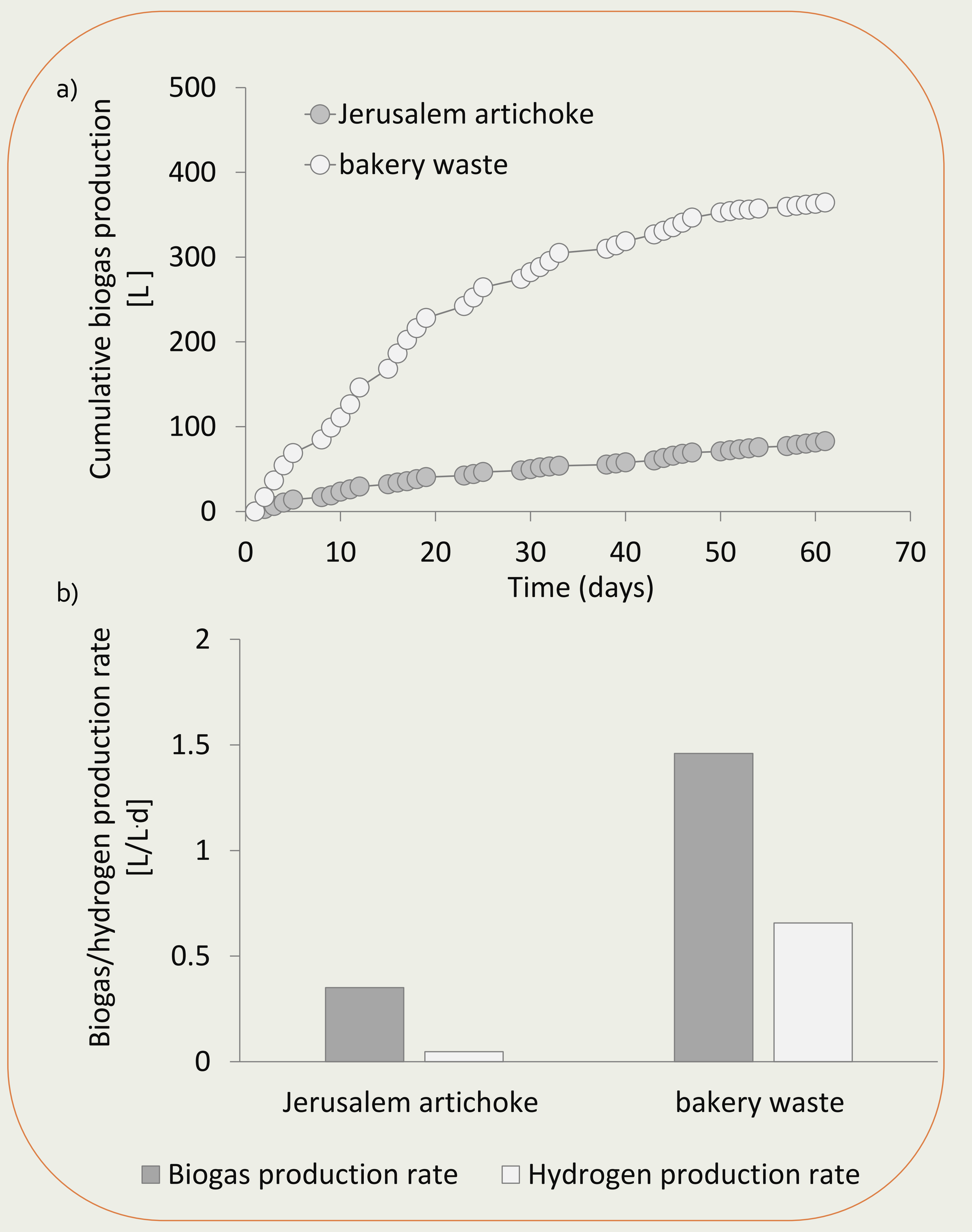

Fig. 2. Cumulative biogas production (a) and biogas/hydrogen production rate (b) in series with Jerusalem artichoke and bakery waste

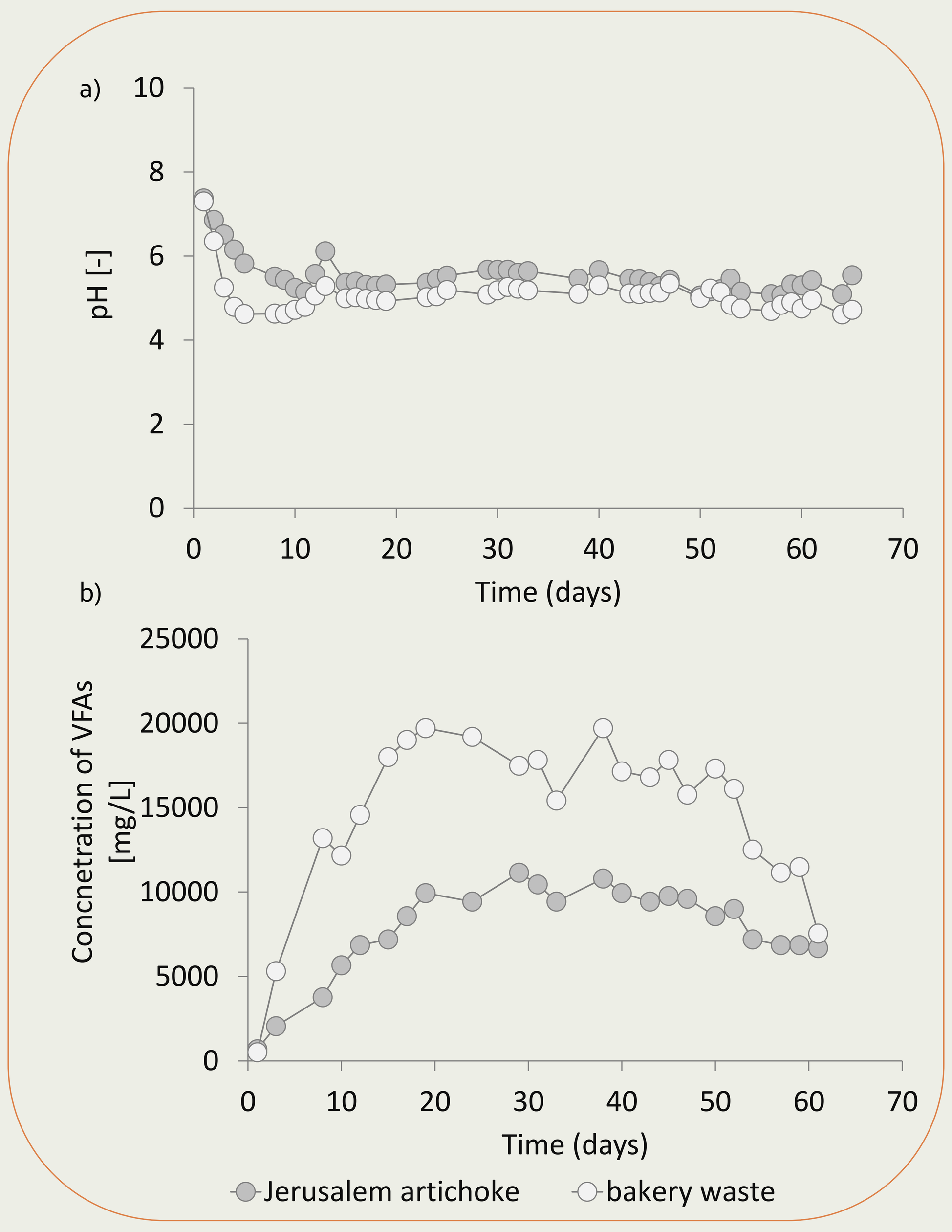

Fig.3. Changes of pH (a) and concentration of volatile fatty acids (b) in series with Jerusalem artichoke and bakery waste.

REFERENCES

1. Zheng, Y., Zhang, Q., Zhang, Z., Jing, Y., Hu, J., He, C., & Lu, C. (2022). Bioresource Technology, 347, 126595. 2. Sampath, P., Reddy, K. R., Reddy, C. V., Shetti, N. P., Kulkarni, R. V., & Raghu, A. V. (2020). Chemical Engineering & Technology, 43(7), 1240-1248. 3. Osman, A. I., Deka, T. J., Baruah, D. C., & Rooney, D. W. (2020). Biomass Conversion and Biorefinery, 1-19.

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biohydrogen production, dark fermentation, Jerusalem artichoke, bakery waste

CONCLUSIONS

Comparison of dark fermentation of Jerusalem artichoke and bakery waste shows that under the same operating conditions, the production rates of biogas and hydrogen (1.46 L/L.d and 0.66 L/L.d, respectively) were higher for the series with bakery waste than for Jerusalem artichoke (0.35 L/L.d and 0.05 L/L.d, respectively).

Dr Habil. Eng. KATARZYNA BUŁKOWSKA, associate professor
Department of Environmental Biotechnology
University of Warmia and Mazury in Olsztyn
katarzyna.bulkowska@uwm.edu.pl