**Kinetic studies of anaerobic digestion of chicken manure with sawdust and wheat straw after fungal pre-treatmet**

Andreja Goršek\*, Darja Pečar

*University of Maribor, Faculty of Chemistry and Chemical Engineering*

*Smetanova 17, SI-2000 Maribor, Slovenia*

*\*Corresponding author: andreja.gorsek@um.si*

**Highlights**

* The pre-treatment was conducted with two white-rot wood decay fungi.
* Anaerobic fermentations of chicken manure with co-substrates were conducted.
* First-order and modified Gompertz kinetic models were employed.
* Kinetic parameters of the fermentation were determined.

**1. Introduction**

Bioenergy is an alternative, cheap and sustainable source of energy compared to non-renewable energy sources such as fossil fuels [1]. Anaerobic fermentation is one of the most promising renewable energy production processes. However, the feasibility of anaerobic fermentation depends on substrate characteristics, operating conditions and fermenter design.

With increases in poultry breeding, huge amounts of manure are produced. Anaerobic fermentation is the most suitable process to deal with this material [2]. Crops and crop residues which mainly consist of lignin, cellulose and hemicellulose are used as co-substrates in these processes. Lignocellulosic biomass pre-treatment is usually necessary to reduce structural obstacles by breaking the polymer chains of lignin and making cellulose and hemicellulose more accessible for microbial attack. Pre-treatment methods are divided into physical, chemical, and biological. Biological ones are based on fungal, microbial and enzymatic pre-treatment.

Fungal pre-treatment is usually conducted using white-rot, brown-rot and soft-rot fungi. White-rot fungi produce lignolytic enzymes (laccase and peroxidases) and they are known as the most efficient in delignification processes [1].

In this study, for wheat straw pre-treatment white-rot fungi, *Pleurotus ostreatus* (WPO) and *Trametes versicolor* (WTV),were used.Three different mass ratios (80:20, 60:40, 50:50) of chicken manure with saw dust (CMS) to pre-treated (WPO, WTV) and ordinary wheat straw (OWS) were used as substrates in anaerobic fermentations. During the fermentations, the volume of produced biogas and CH4 concentration were measured. The main goal of our study was to determine the kinetic parameters of CH4 production during anaerobic fermentation. First-order and modified Gompertz kinetic models were fitted to the experimental data.

**2. Methods**

The pre-treatment was conducted with white-rot wood decay fungi. All fermentations were carried out in thermostated batch fermenters at different temperatures, *ϑ* = (35, 40 and 45) ºC. The single experiment was started by loading the reactor with 5 g of pre-treated substrate, 5 g of inoculum (dry mass) and 20 mL of water. Then the fermenters were purged for 2 min with argon to remove all air and to establish anaerobic conditions. The fermenters were thermostated at the desired temperature for 21 d. During the fermentation, the volume of the biogas produced was measured. It was determined by the water displacement method. The methane concentration was calculated using a Shimadzu GC-2010 gas chromatograph coupled to a thermal conductivity detector TCD. The kinetic data obtained from separate anaerobic digestions were checked for the fitness of first-order kinetics and modified Gompertz equation.

**3. Results and discussion**

First-order and Gompertz kinetic models were used to simulate anaerobic fermentation of a chicken manure with sawdust with pre-treated and ordinary wheat straw at three mass ratios of used substrates. Activation energies and pre-exponential factors for CH4 production during the anaerobic fermentation were determined from the reaction rate constants obtained from first-order kinetic model at different temperatures (Table 1).

**Table 1.** Activation energies and pre-exponential factors for CH4 production during the anaerobic fermentation.

|  |  |  |  |
| --- | --- | --- | --- |
| SUBSTRATE | MASS RATIO | *E*a / kJ mol-1 | *k*0 / d-1 |
| CMS:OWS | 80:20 | 110.8 ± 19.6 | (8.2 ± 1.5) ⋅ 1017 |
| 60:40 |  88.3 ± 12.5 | (1.5 ± 0.2) ⋅ 1014 |
| 50:50 |  72.1 ± 15.9 | (3.2 ± 0.7) ⋅ 1011 |
| CMS:WPO | 80:20 | 103.8 ± 38.7 | (5.5 ± 2.1) ⋅ 1016 |
| 60:40 |  88.8 ± 19.6 | (1.9 ± 0.4) ⋅ 1014 |
| 50:50 |  89.6 ± 14.1 | (2.7 ± 0.4) ⋅ 1014 |
| CMS:WTV | 80:20 | 109.9 ± 22.9 | (6.9 ± 1.5) ⋅ 1017 |
| 60:40 |  79.0 ± 11.6 | (4.7 ± 0.7) ⋅ 1012 |
| 50:50 |  65.8 ± 18.7 | (2.8 ± 0.8) ⋅ 1010 |

We found out from the results of model accuracies, that both models properly describe the experimental data, but it is more suitable to describe CH4 production with the first-order kinetic model, rather than with Gompertz kinetic model. The lowest R2 value for the first-order kinetic model was 0.9780, and for the Gompertz model, 0.9713. The difference can be explained by the instant acceleration of the CH4 concentration at the very beginning of fermentation. Thus, the profiles of CH4 concentration are not the typical sigmoidal curves usually described by the Gompertz kinetic model. Generally, maximum CH4 concentrations determined with Gompertz kinetic model are lower than those determined with the first-order kinetic model.

**4. Conclusions**

During the fermentation of chicken manure, the amount of biogas produced and the CH4 concentrations were measured. The volume of biogas produced was slightly lower when ordinary wheat straw was used as co-substrate, compared to the pre-treated wheat straw. The kinetic parameters of CH4 production during anaerobic fermentation were determined. A comparison between the experimental data and the data calculated by first-order kinetic model and modified Gompertz kinetic model was made. Both models describe the experimental data very well. The kinetic parameters do not significantly differ regarding the substrate; only the activation energies are slightly higher for the pre-treated wheat straw compared to ordinary straw.

**References**

1. Rouches, I. Herpoël-Gimbert, J.P. Steyer, H. Carrere, Renew. Sust. Energ. Rev. 59 (2016) 179–198.
2. C. Li, S. Strömberg, G. Liu, I.A. Nges, J. Liu, Biochemical Eng. J. 118 (2017) 1–10.