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Comparison of the Biochemical Methane Potential of Different Organic Biomass

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Abstract: Anaerobic digestion is often used as an alternative treatment for biowastes. The methane potential and the biodegradability of different biowastes can be estimated by the biochemical methane potential (BMP) tests. This study aimed to determine the BMP and the enzymatic hydrolysis of different organic waste such as milk whey (MW), pig manure (PM), sugarcane bagasse (SB) and aquatic macrophytes (AM) (*Pistia stratiotes*). SB and AM were previously submitted to particle reduction size (< 10 mm) and SB was oven-dried (60 °C for 24 hours). The assays were performed in 125 mL glass bottles at 37 °C. Biogas composition was determined by gas chromatography and the results were evaluated using analysis of variance and Tukey test for mean comparisons ($p < 0.05$). The highest BMP was observed for MW (314 L_NCH_4 kg VS^{-1}) followed by PM (301 L_NCH_4 kg VS^{-1}) and SB (249 L_NCH_4 kg VS^{-1}) and AM (43 L_NCH_4 kg VS^{-1}). The high variation in the methane potential of the studied substrates is related to their different chemical composition and biodegradability rates. It is suggested that co-digestion using a mixture of substrates could increase methane production, since it favors the synergistic effects, increases the methane content and improves the operation of the biodigester.

Key words: agricultural waste, biogas, BMP, anaerobic digestion

1. Introduction

Anaerobic digestion emerges as an alternative treatment to transform biowaste with high polluting potential into added value by-products such as biogas and biofertilizer. In Brazil, the use of biomass represents 32.7% of the global energy matrix 8.5% of the power source, providing approximately 52.000 GW for the electrical system in 2018 (Brazilian Company of Energy Research, 2019). However, biogas production from agro-industrial wastes, animal manure and municipal solid waste (MSW) contribute with only 119 MW, which

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represents less than 1% of the total energy produced by all biomass sources (ANEEL, 2017). Residues used as biomass can come from agroindustrial wastewater, energy crops, sewage sludge, among others (Tian et al., 2018). The characteristics of each residue can result in different methane productions, as well as impacting the reactor operating system. The determination of the methane potential of different types of biomass is a very important key-factor affecting the efficiency of real scale biogas plants.

Thus, this study aimed to determine the biochemical methane potential (BMP) of substrates from different sources such as whey, pig manure, sugar cane bagasse and macrophytes, for comparison purposes regarding methane production and enzymatic hydrolysis rate.

2. Methodology

Substrate and inoculum

The inoculum used in the batch tests was composed of two different types of digestates from biodigesters that treat pig and cattle manure, together with raw cattle manure in the ratio of 1:0,5:0,5 (ww/ww), respectively. Acclimatization was performed according to Edwiges et al. (2018). The substrates used were:

- Sugarcane bagasse (SB): Collected from a local company which produces sugarcane products (Medianeira/Parana);
- Aquatic macrophyte (AM): Pistia stratiotes collected from an Ecological Park (Santa Terezinha de Itaipu/Parana);
- Milk whey (MW): Collected from dairy industry located in Céu Azul/Paraná.
- Pig manure (PM): Collected from a family scale swine breeding confined.

SB and AM were ground to reduce the particle size (<10 mm). SB was dried for 24 hours at 60°C to ensure sample heterogeneity and eliminate extra humidity, allowing the grinding process. The biomass characterization was obtained through the analyzes of total solids (TS), volatile solids (VS) and pH (APHA, 2006).

Biochemical methane potential (BMP)

The determination of the BMP was performed using glass bottles with a capacity of 125 mL, adopting the conditions established by VDI 4630 (2006), since particle size was very low. The batch bottles were kept at 37°C in a water bath and the volume of biogas was measured using a 100 mL glass syringe. The monitoring was performed from the daily biogas production and atmospheric pressure until the daily biogas volume was less than 1% of the accumulated volume. The biogas composition was determined by gas chromatography (ASTM D1945-14, 2014) in a chromatograph (Perkin Elmer - Clarus 680).

Statistical analysis

Analysis of variance (ANOVA) was applied to identify the significant difference between the treatments and the Tukey test ($p < 0.05$) was used to evaluate differences among means.

3. Results and Discussion

The TS of PM, MW and AM was 2%, 6% and 21%, respectively, being the SB the highest TS (87%) (Table 1). From the moisture point of view, PM and MW have potential to be trated anaerobically from conventional wet digestion systems (operational TS under 15-20%). However, AM and SB showed higher TS, indicating co-digestion with liquid biowastes need to be applied in order to be trated by conventional processes. On the other hand, all substrates showed very high VS indicating good potential for bioconversion. SB showed the highest VS (98% TS), followed by AM (94% TS), MW (92% TS) and PM (92% TS). Except from MW the pH of AM and PM in the range of 6.9 to 8.1 is favorable for the growth of methanogenic bacteria (Table 1). The mesophilic inoculum showed essential characteristics for the use of batch tests, which is mainly neutral pH and VS higher than 50% (VDI 4630, 2006).

Table 1 – Characterization of inoculum and substrates

Parameter	Inoculum	Aquatic macrophyte	Sugarcane bagasse	Milk Whey	Pig Manure
TS (%)	3±0.1	21±1	87±1	6±0.1	2±0.1
VS (% TS)	68±1	94±1	98±1	92±1	92±1
pH	7.4	6.9	NA	3.1	8.1

TS: total solids; VS: volatile solids; db: dried basis; NA: not applicable.

The BMP of the MW and PM was 314 and 301 L_N CH_4 kg VS^{-1}, respectively (Table 2). Vivekanand et al. (2018) and Pham et al. (2014) reported lower values in their studies, being 264 and 211 L_N CH_4 kg VS^{-1} for the same type of biomass. This difference can be explained by the influence of the regional swine production system and dairy industrial activity. The BMP of the SB was 249 L_N CH_4 kg VS^{-1} and the macrophyte had the lower BMP 43 L_N CH_4 kg VS^{-1}. This lower result, compared to PM and MW can be explained by the lack of chemical pretreatment in SB and AM to break up lignocellulose, which forms a protective barrier to microorganisms and hinders their decomposition. MW showed the highest methane production due to the presence of non-structural carbohydrates, mainly lactose (Escalante et al., 2017). The SB showed similar behavior, however, it was 35% lower than MW. For Rodriguez et al., (2017), the reduction of the particle diameter increases the contact of the biodegradable matter with the microorganisms but does not improve the yield of the methane production.

Table 2 – Methane production

Substrate	L_N CH_4 kg VS^{-1}	L_N CH_4 kg FM^{-1}
Milk whey	314±24^{a}	17±1^{b}
Pig manure	301±9^{a}	5±0.1^{b}
Sugarcane bagasse	249±18^{b}	212±16^{a}
Aquatic macrophyte	43±3^{c}	8±1^{b}

Different letters indicate significant differences by Tukey test ($p \leq 0.05$).
FM: fresh matter.

Methane production started immediately for all substrates. Hydrolysis showed that the peak of methane production was 149 L_N CH_4 kg VS^{-1} d^{-1} and 53 L_N CH_4 kg VS^{-1} d^{-1} on day two for MW and SB, respectively (Figure 1b). PM showed the highest peak on day six (41 L_N CH_4 kg VS^{-1} d^{-1}) (Figure 1b). However, the rate of hydrolysis remained constant between the second and sixth days due to the degradation stage of carbohydrates, proteins and lipids. In contrast, the rate of AM hydrolysis remained below (5 L_N CH_4 kg VS^{-1} d^{-1}), which may be explained by possible the presence of inhibitory compounds, such as heavy metals, since this type of vegetable can absorb chemical components in their tissues.

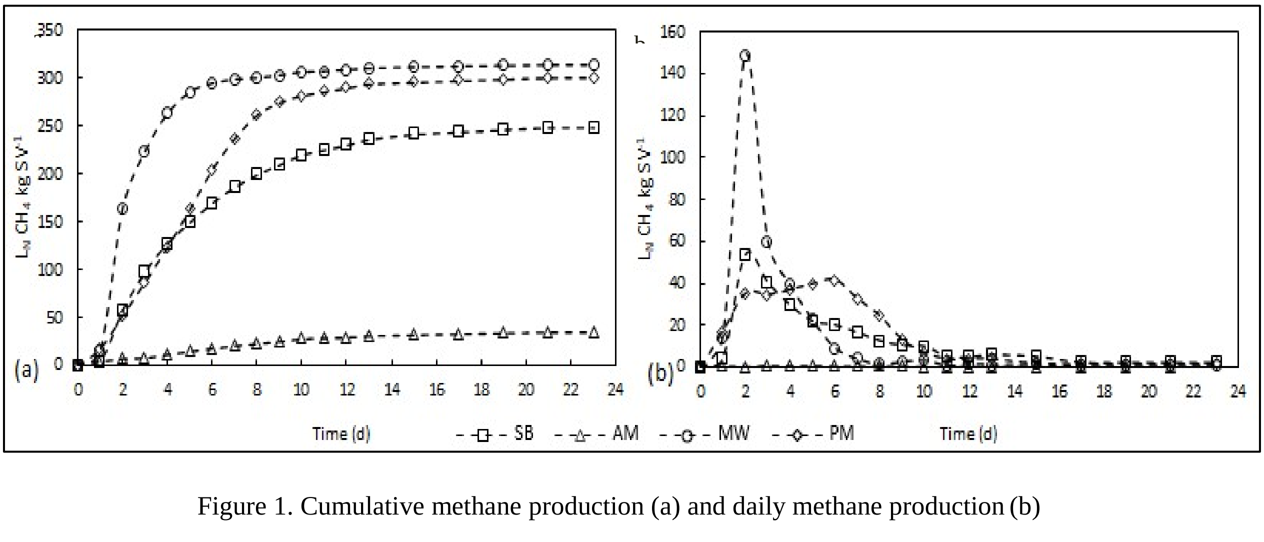

Figure 1. Cumulative methane production (a) and daily methane production (b)

MW: milk whey; PM: pig manure; SB: sugarcane bagasse; AM: aquatic macrophyte.

Analyzing methane production per gram of fresh matter (which is of interest to real scale biogas plants in terms of operational practice), the substrates MW, AM and PM showed lower biogas/methane cumulative values, which can be related to the very low TS content of the substrates MW and PM and the high recalcitrance of AM. In this case, the SB presents higher production (212 L_N CH_4 kg FM^{-1}), when compared to the other substrates, while the PM has the worst case scenario (5 L_N CH_4 kg FM^{-1}) (Table2).

4. Conclusions

There was a difference in the biochemical methane potential of substrates from different sources. Considering a VS basis, milk whey had the highest methane potential (314 L_N CH_4 kg VS^{-1}) and aquatic macrophyte the worst value (43 L_N CH_4 kg VS^{-1}). This difference can be related to the chemical composition of the VS of the substrates. For the operation of full-scale plants, the methane potential on fresh matter basis must be used. In this case the scenario is different, with sugarcane having the greatest potential (212 L_N CH_4 kg $sugarcane^{-1}$) and pig manure the worst, producing only 5 L_N CH_4 kg $pigmanure^{-1}$. This result is due to the differences in humidity of each sample and not only the chemical composition of the SV.

References

Agência Nacional de Energia Elétrica - ANEEL. Banco de Informações de Geração. Brasília: (2017).

American Public Health Association - APHA. Standard methods for the examination of water and wastewater.21 ed. Washington: American Water Works Association, 2005. 1368 p.

EDWIGES, Thiago et al. Influence of chemical composition on biochemical methane potential of fruit and vegetable waste. Waste Management, v. 71, p. 618-625, 2018.

ESCALANTE, H., CASTRO, L., AMAYA, M. P., JAIMES, L., JAIMES-ESTÉVES, J. Anaerobic digestion of cheese whey: Energetic and nutritional potential for the dairy sector in developing countries. Waste management. v. 71, p. 711-718, 2017. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/29017872> Accessed on: 20 nov. 2018.

TIAN, Hailin, et al. A proposed mechanism for the ammonia-LCFA synergetic co-inhibition effect on anaerobic digestion process, Chemical Engineering Journal (2018), Vol. 349, pág. 574 – 580. Doi: https://doi.org/10.1016/j.cej.2018.05.083

HOLLIGER, Christof, et al. Towards a standardization of biomethane potential tests. Water Science & Technology (2016), Pág. 2515 - 2522. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/27973356>. Accessed on: 13 nov. 2018. Doi: https://doi.org/10.2166/wst.2016.336.

MINISTÉRIO DE MINAS E ENERGIA - MME (Brasil). Empresa de Pesquisa Energética - EPE. Relatório Síntese. Balanço Energético Nacional 2019: Ano base 2018, Rio de Janeiro: EPE, ano 2019, v. 1, n. 1, p. 1, maio 2019.

PHAM, C. H.; TRIOLO, J. M.; SOMMER, S. G. Predicting methane production in simple and unheated biogas digesters at low temperatures. Applied Energy, v. 136, p. 1–6, 2014. Elsevier. Available at:

<https://www.sciencedirect.com/science/article/pii/S030626191400868X>. Accessed on: 23 nov. 2018.

RODRIGUEZ, C., ALASWAD, A., BENYOUNIS, K. Y., & OLABI, A. G. Pretreatment techniques used in biogas production from grass. Renewable and Sustainable Energy Reviews, (2017). v.68, p. 1193–1204.

Available at: <https://research-portal.uws.ac.uk/en/publications/pretreatment-techniques-used-in-biogas-production-from-grass >. Accessed on: 20 nov. 2018. Doi:10.1016/j.rser.2016.02.022.

VEREIN DEUTSCHER INGENIEURE. VDI 4630: Fermentation of organic materials Characterisation of the substrate, sampling, collection of material data, fermentation tests. Düsseldorf, 2006. 92 p.

VIVEKANAND, V.; MULAT, D. G.; EIJSINK, V. G. H.; HORN, S. J. Synergistic effects of anaerobic co- digestion of whey, manure and fish ensilage. Bioresource Technology, v. 249, p. 35–41, 2018. Elsevier. Available at: <https://www.sciencedirect.com/science/article/pii/S0960852417317340>. Accessed on: 23/11/2018.