Antibiotic Residuals and Anaerobic Digestion of Dairy Manure

November 2020

Introduction

Critically important antibiotics include fluoroquinolones, beta-lactams, and macrolides, and highly important antibiotics include tetracyclines and sulfonamides. Part 1 of *Antibiotic Residues in Dairy Manure*[1] provides a full list of antibiotics used on dairies and their level of importance as antimicrobials for human medicine according to the World Health Organization.

Anaerobic digestion (AD) is an advanced manure treatment technology where manure and other organics are degraded by a system of operative microbes naturally existing under anaerobic (no oxygen) conditions, producing biogas (largely methane and carbon dioxide) and a liquid effluent. Antibiotic residuals and AD can be looked at in two ways:

1) The impact antibiotic residuals may have on AD operative microbes.
2) The impact AD may have on residual antibiotics in manure.

Impact of antibiotic residuals on AD performance

AD system operations vary in the loading, mixing, hydraulic retention time (HRT), and temperature conditions that all influence the digester microbial community[2] and the ability of the digester to mitigate antibiotic residuals and antibiotic resistance (AR)[3]. AD systems are not designed nor operated for the specific purpose of mitigating residual antibiotics.

Oxytetracycline has been shown to disrupt operative AD microbial groups, including methanogens, resulting in reduced biogas yields. In some studies, biogas production recovered over time after an initial inhibition occurred. Higher concentrations of oxytetracycline have also been shown to significantly impact the volatile fatty acid (VFA) generation and resulting methane yields; however, the methanogens were found to be more resilient to these impacts under stable AD conditions.[4]

Most AD system research with cattle manure containing residual antibiotics have not represented real world conditions and have focused on the antibiotic residue oxytetracycline. Research is needed that combines the effects of antibiotic residue mixtures, concentrations, and AD system operating conditions to accurately assess and optimize antibiotic residual mitigation.

Impact of AD on residual antibiotics

Antibiotic residue degradation patterns vary with the class of the antibiotic and its concentration. In laboratory tests, sulfamethazine did not degrade regardless of concentration, while ampicillin had concentration-dependent degradation rates. Laboratory tests also showed a third pattern whereby lower initial concentrations of florfenicol did not generate the formation of persistent degradation products.[5] Within one class of antibiotics, degradation rates can significantly differ as well. A study of cow manure anaerobic digester trials found a 30% difference in degradation rates between sulfadiazine and sulfamethazine, which differ by only 2 methyl groups.[6]

Overall, steadily operated digesters and those at higher temperatures are generally better at degrading antibiotics than those operating at lower temperatures or with variability.[4] One laboratory study found 10% higher reduction in oxytetracycline in a two-stage continuous-flow mixed AD as compared to a less stable single-stage AD system, both operating at mesophilic conditions of 100°F with a HRT of 20 days using dairy manure feedstock with oxytetracycline loading rates of 3 mg/L.[7]

In a similar laboratory study, oxytetracycline degradation was found to be 21 to 38% higher where the single-stage AD was operated at thermophilic conditions of 130°F.[8] The higher oxytetracycline degradation rates observed in thermophilic AD with dairy manure feedstock have been attributed to the optimized microbial kinetics and formation of pyrolysis reactions occurring at higher operating temperatures.[9,10]

Authors

Lauren Ray Email: ler25@cornell.edu
Curt Gooch Email: cag26@cornell.edu

---

[1] PRO-DAIRY Fact Sheet Series on Antibiotic Residues in Dairy Manure Part 1: Critically important antimicrobials labeled for dairy use, https://prodairy.cals.cornell.edu/environmental-systems-mgt/environmental-considerations/amr/.
[2] Kundu, K., S. Sharma, and T. R. Sreekrishnan. 2017. Influence of process parameters on anaerobic digestion microbiome in bioenergy production: towards an improved understanding. BioEnergy Res. 10:288–303.
[3] Youngquist, C. P., S. M. Mitchell, and C. G. Cogger. 2016. Fate of antibiotics and antibiotic resistance during digestion and composting: A review. J. Environ. Qual. 45:537–545.
[4] Oliver, J. P., C. A. Gooch, S. Lansing, J. Schueler, J. J. Hurst, L. Sassoubre, E. M. Crossette, and D. S. Aga. 2020. *Invited review*: Fate of antibiotic residues, antibiotic-resistant bacteria, and antibiotic resistance genes in US dairy manure management systems. J. Dairy Sci. 103:1051-1071.
[5] Mitchell, S. M., J. L. Ullman, A. L. Teel, R. J. Watts, and C. Frear. 2013. The effects of the antibiotics ampicillin, florfenicol, sulfamethazine, and tylosin on biogas production and their degradation efficiency during anaerobic digestion. Bioresour. Technol. 149:244–252.
[6] Spielmeyer, A., B. Breier, K. Groissmeier, and G. Hamscher. 2015. Elimination patterns of worldwide used sulfonamides and tetracyclines during anaerobic fermentation. Bioresour. Technol. 193:307–314.
[7] Akyol, C., O. Ince, Z. Cetecioglu, F. U. Alkan, and B. Ince. 2016. The fate of oxytetracycline in two-phase and single-phase anaerobic cattle manure digesters and its effects on microbial communities. J. Chem. Technol. Biotechnol. 91:806–814.
[8] Akyol, C., G. Turker, O. Ince, E. Ertekin, O. Ustuner, and B. Ince. 2016. Performance and microbial community variations in thermophilic anaerobic digesters treating OTC medicated cow manure under different operational conditions. Bioresour. Technol. 205:191–198.
[9] Varel, V. H., J. E. Wells, W. L. Shelver, C. P. Rice, D. L. Armstrong, and D. B. Parker. 2012. Effect of anaerobic digestion temperature on odour, coliforms and chlortetracycline in swine manure or monensin in cattle manure. J. Appl. Microbiol. 112:705–715.
[10] Lin, H., J. Zhang, H. Chen, J. Wang, W. Sun, X. Zhang, Y. Yang, Q. Wang, and J. Ma. 2017. Effect of temperature on sulfonamide antibiotics degradation, and on antibiotic resistance determinants and hosts in animal manures. Sci. Total Environ. 607–608:725–732.

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2016-68003-24601. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.