Estimating anaerobic digester effluent volume when processing co-digestion feedstocks

(Part 2: Application)

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Volume reduction estimate application

Anaerobic co-digestion (AcoD) influent biodegradable volatile solids (VS) are converted to biogas, reducing both effluent mass and volume. A portion of the existing on-farm AcoD operations measure influent volume and measure some basic influent characteristics. This basic input data allows for a reasonable estimate of effluent volume reduction using the Biodegradability Approach[1]. This fact sheet provides an array of results applying this method on representative on-farm AcoD scenarios (Table 1).

The assumptions used in Table 1 include: 1) density of each feed stream of 8.34 lbs./gallon, 2) typical AD hydraulic retention time (HRT, 30 days), average reactor temperature of 95°F, 3) estimated conversion of each feedstock to biogas estimated based biochemical methane potential (BMP) test or on published data, and 4) an average dry biogas composition of 62% CH_4 and 38% CO_2.

The biodegradability of raw dairy manure and several candidate co-digestion organic materials, expressed as their BMP (often noted as B_0) are shown in Table 1. Methane production per unit of mass of manure volatile solids (VS) fed is inherently variable. Thus, more reliable estimates require multiple influent BMP tests. An example of biogas production and associated volume reduction estimates in Table 1 is: An AcoD mixed system with an active reactor volume of 3.0 million gallons, receives a total average daily feed volume of 100,000 gpd, resulting in an average HRT of 30 days. The feed stream is from two sources: 70,000 gpd of dairy barn effluent **[column 1]** (10 percent total solids (TS) content **[4]** with 85 percent of the TS as VS **[5]**), and cheese whey received at 30,000 gpd **[2]** (7% TS content **[4]** with 85 percent of the TS as VS **[5]**). The assayed BMP estimate for raw manure is 247.2 mL CH_4/g VS_{manure} consumed **[3]** and for cheese whey is 423.6 mL CH_4/g VS_{whey} **[3]** consumed.

The total hydraulic load of 100,000 gpd is reduced by 4,058 gallons or about 4.1 percent of the influent **[10]** AcoD digester feed volume (whey influent volume is reduced by 1,395 gpd, manure influent reduced by 2,663 gpd). Thus, the additional amount to be handled/stored/land-applied due to the whey is 28,605 gpd, which is about 4.6 percent less than the whey fed. In contrast, for highly biodegradable feedstreams with low water content, such as vegetable oil, the volume reduction for the added co-digestate can be considerable (83 percent). Overall, the estimates provided in Table 1 are based on several assumptions and values are provided for initial data points only. Guidance of a qualified co-product management engineer and/or scientist should be sought by the dairy operator when volume reduction values are part of a business analysis.

Observations for Table 1 example estimate values

- All values are independent estimates for the various components digested separately. Biogas production potential for the mixture of a feedstock(s) and manure to either increase or decrease overall biogas generation is not considered although both have been observed.
- Materials are representative of the broad range and characteristics of co-digestion feedstocks available.

TABLE 1. Predicted change in digester influent vs effluent volume per 100,000 gallons of manure and co-digestate total feed using Biodegradability Approach Volume Reduction (Vol. Red.) Estimate[1].

Co-Digestate Feedstock [1]	% Vol. Fed [2]	B_0 (mL CH_4/ g VS) [3]	TS (%) [4]	VS/ TS (%) [5]	CH_4 Gaseous Mass, Pound [6]	Total Biogas Mass, Pound [7]	Vol. Red. for Manure (%) [8]	Vol. Red. for Co-Digestate (%) [9]	Total Vol. Red. (%) [10]
Barn Effluent	100	247.2	10	85	12,500	33,600	4.0	N/A	4.0
Cheese Whey	30	423.6	7	85	13,300	35,600	4.0	4.8	4.3
	50				13,800	37,000	4.0	4.8	4.4
Ice Cream	10	502.3	11	96	14,400	38,700	4.0	10.2	4.6
	20				16,300	43,900	4.0	10.2	5.3
Cabbage	30	256.5	65	92	36,200	97,100	4.0	29.4	11.6
	50				52,000	140,000	4.0	29.4	16.7
Potatoes	30	334.5	18	92	18,700	50,100	4.0	10.6	6.0
	50				22,800	61,100	4.0	10.6	7.3
Feed Refusals	30	296.1	85	90	49,200	132,000	4.0	43.4	15.8
	50				73,700	198,000	4.0	43.4	23.7
Used Oil, Vegetable	10	648.5	85	98	43,400	116,700	4.0	99	14.0
	20				74,400	199,700	4.0	99	23.9

[1]Digester operating conditions assumed: 95°F (35°C); HRT 30 day; Biogas 62% CH_4 38% CO_2; VS S.G.=1.0 (1,000 kg m^{-3}); Ignores biogas H_2O.

- The volume reduction portion due to manure degradation is constant (3.8 percent).
- The percentage of off-farm co-digestion feed reflects typical practice, and in the case of highly biodegradable streams, is constrained by the need to maintain stable operation without significant additional monitoring, controls, or feed stream chemistry adjustment.
- Results for two of the three wastes with the highest biodegradability (whey, ice cream, oil) where low volume reductions due to their dilute nature (whey, ice cream). In the case of vegetable oil, it was nearly totally consumed due to the low moisture content and high biodegradability.
- A specific feedstock's estimated volume reduction can have a very wide range (4.6 to 99 percent).
- Since in many cases the practical portion of the total digester feed is constrained, the total reduction of the AcoD discharge relative to the feed is often modest (4 to 10 percent).

Further considerations

To obtain more reliable predictions, the feedstock consistency needs to be characterized and BMPs determined. The AcoD operating conditions for temperature and HRT should be in alignment with the BMP assay used.

It is noteworthy that, while it is not unusual for the overall estimated volume reduction to be in the four to 10 percent range as shown in Table 1, depending on the nature of the feedstocks and system operating factors, potential estimated volume reductions for the non-manure feedstocks can be considerable.

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[1]Labatut, R.A., Morris, J.W. and Gooch, C.A. (2022). "A Practical Approach for Estimating Influent-Effluent Mass Flow Differences in Dairy Manure-Based Anaerobic Co-Digestion Systems," Journal Applied Engineering in Agriculture - Vol. 38(1): 165-176 © 2022 American Society of Agricultural and Biological Engineers ISSN 0883-8542 https://doi.org/10.13031/aea.14180.

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