Bio-methane potential (BMP) of sieved dairy manure with condensed distillers solubles (CDS) and cheese whey

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Objective:

This study aims to assess the bio-methane potential of sieved dairy manure with different organic byproducts including condensed distillers solubles (CDS) and cheese whey. In addition, for comparison purposes mixtures of chicken grease and food waste were added.

Materials and methods

Dairy manure was sampled from the Dairy Center at University of Minnesota St Paul and it was sieved with 2.4 mm mesh to remove large particles. CDS, sometimes referring to “corn syrup”, was collected at the corn ethanol plant of Guardian Energy LLC at Janesville, Minnesota by AURI staff Alan Doering. Cheese whey was collected at Food Science Department at University of Minnesota Saint Paul. Kitchen waste was collected from cafeteria of a local high school. Chicken fat, the grease part of chicken processing wastewater, was sampled from a chicken processing plant (Golden Plump, Minnesota).

Substrate mixtures were prepared by mixing sieved manure and different source of organic byproducts, as shown in Table 1. The treatment A was the digestion of pure manure, and treatment B and C were co-digestion of manure with different level of the cheese whey. By comparing the treatment B, C and A, the co-digestion effects of cheese whey were evaluated. Similar experiments were done on CDS and its effects were evaluated by comparing the treatment A and treatment D and E. Treatment F and G were co-digestion of both CDS and cheese whey with manure. Treatment H and I co-digested food waste, chicken fat, CDS and cheese whey as a comparison.

Table 1. Substrate mixtures composition

Treatment ID.	Food waste, % VS	Chicken fat, % VS	Liquid manure, % VS	CDS, % VS	Cheese whey, % VS
A	0%	0%	100%	0%	0%
B	0%	0%	80%	0%	20%
C	0%	0%	60%	0%	40%
D	0%	0%	80%	20%	0%
E	0%	0%	60%	40%	0%
F	0%	0%	80%	10%	10%
G	0%	0%	60%	20%	20%
H	5%	5%	80%	5%	5%
I	10%	10%	60%	10%	10%
Inoculum blank (control)	0%	0%	0%	0%	0%

Biological methane (or bio-methane) potential assays were performed in triplicate according to Angelidaki et al. (2009). The batch experiments were performed in serum bottles of 0.15 L with a working volume of 0.1 L. Substrates (sieved dairy manure through 2.4 mm mesh and mixtures) and anaerobic inoculum were added to each bottle. The substrate concentration based on volatile solids content (VS) was 2 gVS/L. The inoculum to substrate ratio of 2 to 1 was used based on VS content. The inoculum used came from a full-scale anaerobic digester processing sludge (Blue Lake WWTP, Shakopee, MN). The prepared bottles were incubated at 35 ±2°C and shaken continuously at 150 rpm. The experiments were conducted in triplicate for 40 days. The amount of biogas produced was collected by water displacement of a saturated solution of hydrochloric acid at pH 2 in a calibrated glass cylinder manometer. Assays with inoculum only were used as a control. The methane produced from the inoculum (from the control bottles) was subtracted from the sample assays. The biogas values presented are expressed for standard temperature and pressure (STP) conditions (0°C, 1 atm).

Results and Discussion

Substrate composition

Pure substrates were analyzed and results are shown in Table 2. Different units were used in the table 2 based on the convenience of the measurement. Chemical composition of substrates indicates that (i) cheese whey contains the lowest concentration of solids, similar to the sieved manure, which contains around 6% of TS (Table 2). The rest of the organic wastes have much higher solid content. (ii) Both CDS and cheese whey seem to have high biodegradability as expressed by the high concentration of volatile solids i.e about 81% and 92% for CDS and cheese whey.

Table 2 Characteristics of substrates used in the experiments (n=2).

Parameter	*Sieved manure (g/L)*	*CDS (g/L)*	*Cheese whey (g/L)*	*Food waste (% g/g wet)*	*Chicken grease (% g/g wet)*
Total solids, TS	58.8±0.2	256±5.0	65.0±5.3	32.7±7.9	56.9±12.8
Fraction of Volatile solids, VS (% of TS)	77.2±0.1	81.3±0.3	91.8±0.7	93.2±0.2	97.6±0.1

Co-digestion of manure with cheese whey

From our BMP results (Fig. 1), it can be concluded that cheese whey can be used as co-substrates of sieved dairy manure. The inclusion of 20% (in VS basis) of the cheese whey alone did not significantly increase of biogas production, but it increased the biogas production rate. Up to 40% of cheese whey VS in dairy manure had increased methane production by 6% in average compared to pure dairy manure. This result seems to be low, compared to other co-digestion materials we tested at this project. But it is understandable because cheese whey consists mainly of carbohydrates which have lower energy content than lipids and proteins. Although co-digestion with cheese whey didn't substantially improve methane production, it can increase the total methane generation in anaerobic digestion facilities due to the introduction of an additional waste stream. It also removed the biodegradable composition in cheese whey, which otherwise can't be separately achieved without the combination with dairy manure in anaerobic digestion. Carbohydrates as substrate may be favored in anaerobic digestion because of the easily biodegradability indicated by a larger hydrolysis constant than that of lipids and proteins (Mata-Alvarez, Mace et al. 2000), but this effect may be masked in BMP assays as a result of the high VS ratio of inoculum to substrate.

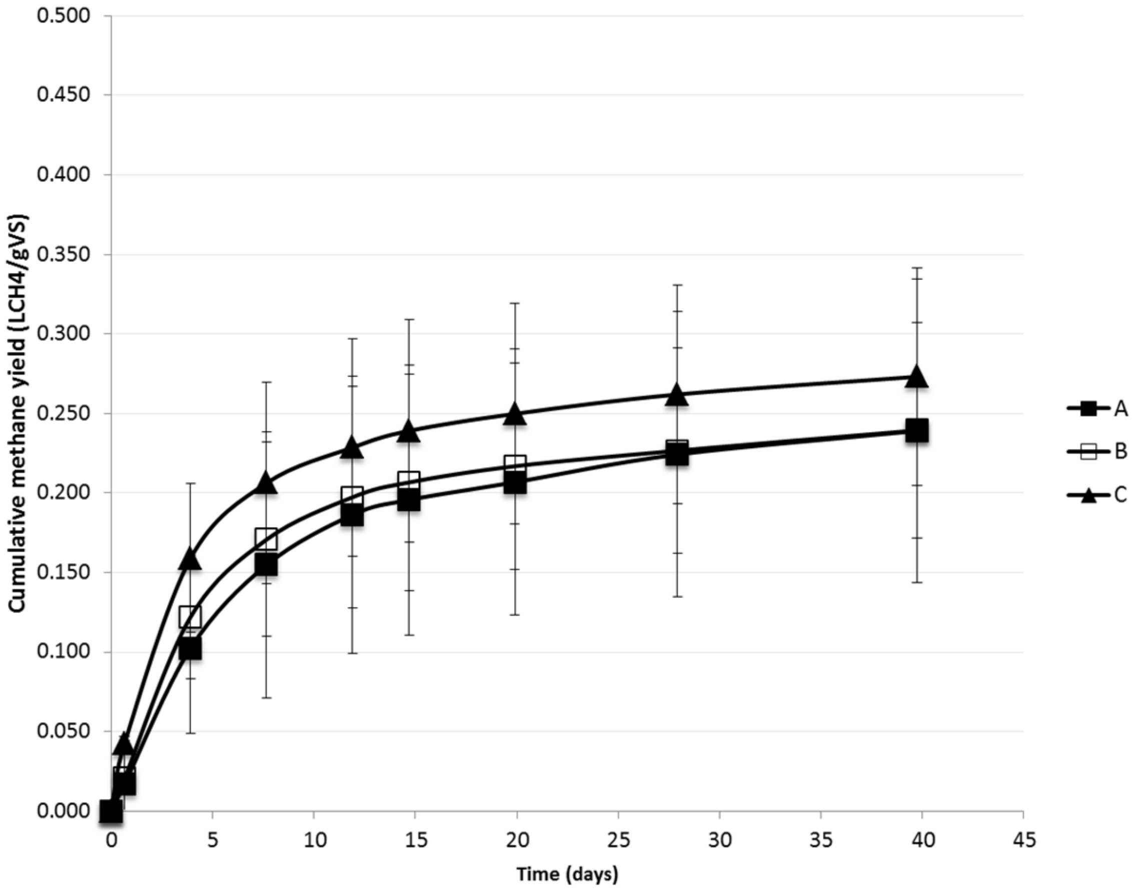

Figure 1 Anaerobic co-digestion of cheese whey with manure

Co-digestion of manure with CDS

From our BMP results (Fig. 2), it can be concluded that CDS can be used as co-substrates of sieved dairy manure. The combination of 20% (in VS basis) of CDS allowed the increase of biogas production. The CDS addition up to 40% increased methane production by 33% in average. The improvement by CDS addition is consistent with literature observations, e.g., 55% increase in methane yield based on degraded VS due to the addition of corn thin stillage between 20% and 40% (Crolla 2013). This is mainly a result of high energy content of CDS or thin stillage itself, indicated by methane yields between 0.6 to 0.7 LCH_4/gVS (Schaefer and Sung 2008; Lee, Bae et al. 2011) . Inclusion of CDS or thin stillage in anaerobic digestion obviously benefits methane generation. The limitation of the BMP analysis is that it cannot estimate the alkalinity needed for this co-digestion; therefore it should be extremely cautious to increase its percentage in substrate which may inhibit methane production once too high.

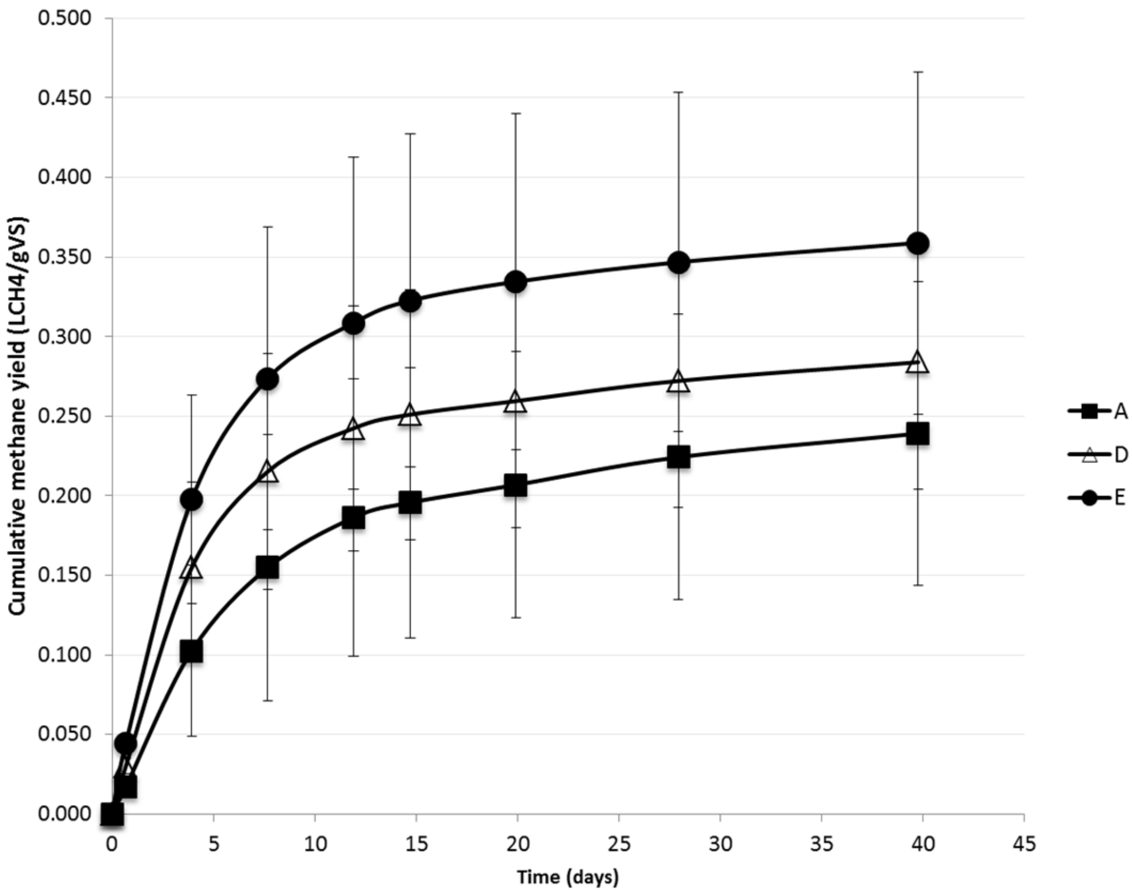

Figure 2 Anaerobic co-digestion of CDS with manure

Accumulative methane production from anaerobic digestion

The overall BMP analysis results are shown in Fig. 3. It can be seen that the lowest cumulative methane production is from sieved manure alone (Sample A) i.e. 0.24 LCH_4/gVS. The mixture that provides a clearly higher methane potential is sample G with up to 0.45 LCH_4/gVS followed by Sample E and Sample H with up to 0.36 LCH_4/gVS (Fig. 1), which is about a factor of 1.5-2 higher than manure alone

(Sample A). Sample G contains the highest portions of both cheese whey and CDS i.e. 20% of each. This indicates that this combination seems to be more appropriate. Interestingly, this combination seems to be more effectively than using either CDS or cheese whey alone (Sample C and E). CDS seems to be a slightly better substrate than cheese whey when used alone with a percentage up to 40%. It is important to mention that the dairy manure used for these experiments was obtained from the U of M dairy barn and not from Jerlindy Farm as in previous experiments on this project. The results regarding biodegradability of sieved manure obtained here were higher than in the previous report i.e. 0.1 LCH_4/gVS vs 0.24 LCH_4/gVS. However; both values are within the range previously reported in literature i.e. up to 0.26 LCH_4/gVS (Frigon, Roy et al. 2012).

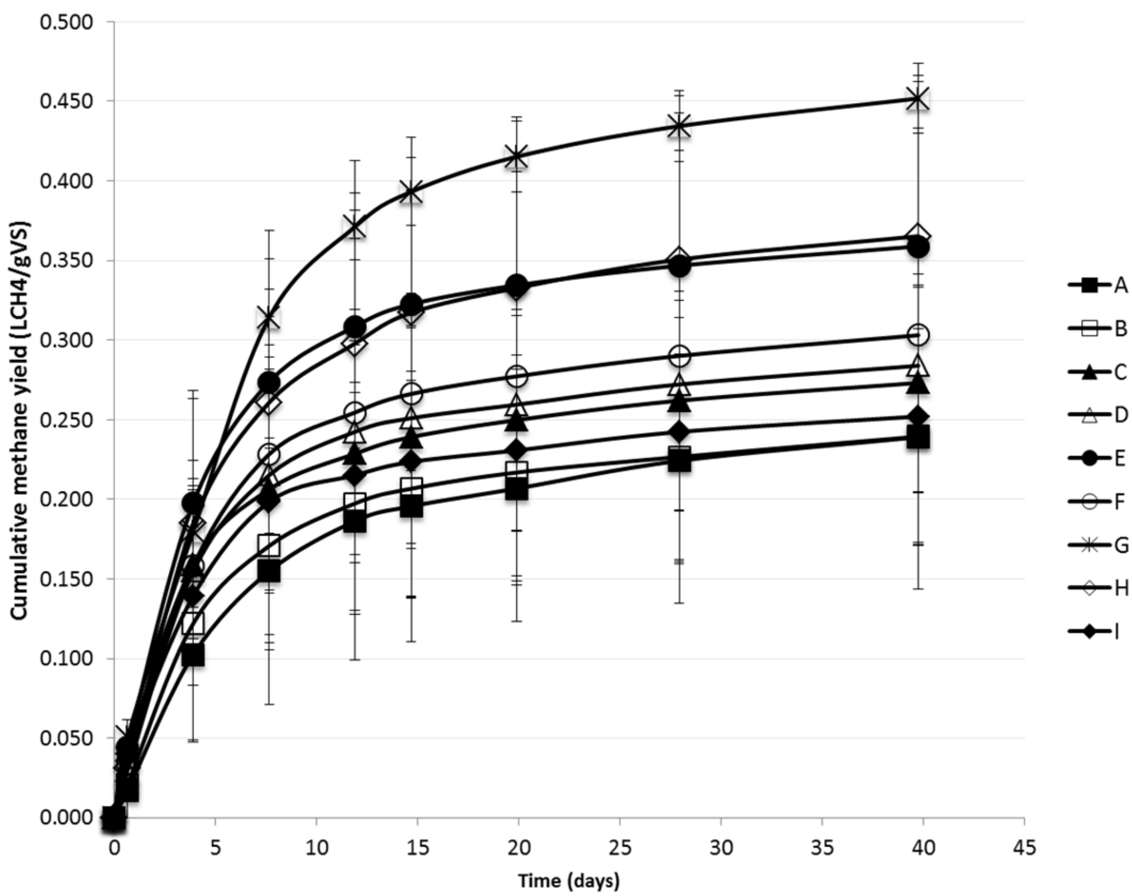

Figure 3. Cumulative methane production (LCH_4/gVS) of all the samples (from A to I mixtures) (see Table 2).

Furthermore, the co-digestion of food waste, chicken fat, cheese whey and CDS with sieved manure was evaluated as well. Having a 5% of each substrate (Sample H) seems to provide a more balanced substrate than 10% (Sample I) allowing a higher methane yield i.e. 0.36 LCH_4/gVS vs 0.25 LCH_4/gVS.

Overall, synergistic effect of combining various substrate sources was generally observed in this study. The reason could be balanced energy source and various nutrients in the mixed media that facilitates microbial growth thus hydrolysis, acedogenesis and methanogenesis. Further confirmation studies are necessary to identify the mechanism of synergetic effect. But again, introduction too high level of feed waste or chicken grease may induce inhibition by fats, thus should be cautious when dealing with co-digestion.

References

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