Influence of dried distillers grains with solubles (DDGS) in dairy cows diet on fugitive manure methane emission and on manure bioenergy production potential

Massé Daniel I.[1], Jarret Guillaume[1]*, Benchaar Chaouki[1]
(1) Dairy and Swine Research and Development Centre, Agriculture and Agri-Food Canada, 2000 College Street, Sherbrooke, Quebec, Canada J1M 0C8.
**Corresponding author:* Guillaume.Jarret@agr.gc.ca

Abstract
The objectives were to investigate **a)** the effect of fat level in dairy cow diet on i) manure fugitive CH_4 emissions and ii) bioenergy potential recovery; **b)** the effect of bedding type (wood shaving, straw and peat moss) on manure fugitive CH_4 emissions and **c)** the effect of complete removal of storage tank sludge and of the emptying frequency on manure fugitive CH_4 emissions. Three diets were formulated: a 0% corn of dried distillers grains with solubles (DDGS0), a DDGS10 and a DDGS30. The fugitive CH_4 emission and the bioenergy production (L.day-1.cow-1) increased significantly by 15% and 14 % respectively for the slurry from DDGS30 diet. The addition of wood shaving and straw did not affect significantly the fugitive CH_4 emission whereas the addition of peat moss increased the emission by 27%. The removal of sludge reduced the fugitive CH_4 emission by 96.5%. The emptying 2 or 4 times the tank reduced the fugitive CH_4 emission by 42 or 79%, respectively.

Introduction
Methane (CH_4) is one the principal agricultural GHG. It is produced by enteric fermentation from ruminant animals [1] and by anaerobic digestion (AD) of manure in livestock buildings and manure storages [2]. The emission level of CH_4, during manure storage is affected by environmental factors such as storage temperature [3], storage duration [4], manure composition and bedding content [5]. Environmental legislation and public concern about the environmental footprint of livestock productions have increased pressure on producers to take measures to reduce atmospheric and environmental pollution. Among all measures proposed to reduce environmental pollution from the livestock sector, animal nutrition has a strong potential to reduce enteric CH_4 emissions and the capture of biogas emission during the AD of manure. Biogas production combined with on-farm power/heat generation seems the most logical measure to replace fossil fuel needs. The addition of fat to a diet reduces enteric CH_4 emission [6]. However few studies have shown if that reduction on enteric CH_4 emission could have an incidence on the fugitive CH_4 emission during storage or AD processes. The recent increase in biofuel by-products, such as corn dried distillers grains with solubles (DDGS), which are rich in fat could be of interest to include in animal diets. These by-products can replace cereals and soybean meal in animal feeds and reduce the natural resources requirement of the livestock sector. Previous research efforts have investigated the use of DDGS in diets to reduce enteric CH_4 emissions [6] and evaluated the impacts on manure production, characteristics and CH_4 emission during mesophilic AD for swine [7]. No previous studies have assessed the effect of corn DDGS on enteric CH_4 emission and on manure quantity and characteristics and fugitive CH_4 emission during storage and CH_4 production during AD from dairy cows under Canadian climatic conditions. Jarret et al., (2011) [7] showed that the introduction of DDGS in the diet could modify the quantity and the characteristics of manure and thus alter the GHG budget of manure during storage and AD by increasing the fugitive CH_4 emission and production. There is a need for scientifically sound data on biogas potential of raw manure from cattle fed different diets as well as for mixtures of raw manure and beddings. The lack of information on fugitive CH_4 emission from mixtures of raw manure with different bedding types justified the present investigation. Bedding is usually made using straw or wood shavings. Due to the low availability of wood shavings and high cost of straw, some producers are showing interest in using peat moss. Manure management practices can also influence GHG emissions. An option to reduce emissions from the barns and indoor storage is complete and more frequent removal of manure. However, there are no data for the Canadian climatic conditions and manure management practices regarding the effect of sludge removal and tank emptying frequency on

fugitive CH_4 emission. Within this context, the objectives of this study were to investigate the effect i) of three diets (a 0% of corn DDGS diet, a 10% of corn DDGS and 30% of corn DDGS): a) on fugitive CH_4 emissions over a 4-month storage trial; b) and on the bioenergy potential recovery from dairy slurry manures; ii) of three bedding types (wood shavings, straw and peat moss) and iii) of two types of manure management (with or without residual sludge in the storage tank) on fugitive CH_4 emissions over a 4-month storage trial. The aim of the present study was to give data on fugitive CH_4 emission during storage as a function of animal diet and manure management practices and to give advice to farmers about the best management practices (BMP) to reduce these fugitive emissions.

Material and Methods

Experimental design

As part of an integrated study to assess the carbon footprint of milk products in Canada, the raw slurry used in this study was provided by an animal experiment conducted to evaluate the impact of the level of corn DDGS as fat source in Holstein cow's diets on enteric CH_4 emissions, and milk performance. Sixteen lactating Holstein cows (645 ± 49 kg) were used in the experiment and fed diets containing increasing level of corn DDGS (0 %- DDGS0, considered as the control diet -, 10% – DDGS10 -, 20% – DDGS20 - and 30% - DDGS30-). The design of the animal trial was made in a 4 (diets) x 4 (periods of diet test) Latin square. For this study, we used the raw slurry from three diets DDGS0, DDGS10, DDGS30. The composition of diets is provided in Table 1 (Benchaar et al. 2013). Urine and faeces were collected from the first period of animal trial separately and pooled daily together per diet in 200-L containers and then stored at 4˚C. In order to have enough material to conduct the CH_4 emissions trials, feces and urine were collected over five consecutive days from three dairy cows fed the control diet, and on three consecutive days from two dairy cows fed the corn DDGS10 and DDGS30 diets. At the end of the collection period, slurries were homogenized per diet and subsampled for analyses.

Incubations set up

Storage simulation was performed over a 4-month period using 54 (± 1) L plexiglas storage structures located in a controlled-environmental chamber operated at 20±1˚C. Twenty six structures were used: 12 for testing diets and manure management; 12 for testing bedding types and manure management; and 2 for quantifying the CH_4 emission from the residual manure storage sludge. Bioenergy production was performed also over a 4 month period using six 54 (± 1) L sequencing batch reactors (SBR) located in a controlled-environmental chamber operated at 25 (± 1) ˚C. The hydraulic retention time (HRT) was 30 days. The SBRs were operated as follows: feed and react period of two weeks each. The organic loading rate was equivalent to 3g $COD.L^{-1}.day^{-1}$ during the feeding period. The six reactors were fed over a 3-month period in order to reach a steady state operation. The last month was used to determine the daily biogas production.

Monitoring Gaseous emission

All storage structures and SBRs were closed hermetically in order to measure daily the production of biogas with wet tip gas meters. Biogas samples were collected once a week and analysed with a Hach Carle 400 AGC gas chromatograph (Hach, Loveland, CO.) to determine the percentage and the concentration of CH_4 in the biogas. Methane emissions were determined by the following equations: Daily CH_4 production: $V\ CH_4\ (n) = V\ (n) \times CH_4\ (n)$; Cumulative CH_4 production over the storage period: $V\ CH_4 = \Sigma\ VCH_4\ (n)$; Cumulative specific CH_4 production over the storage period: Specific $V\ CH_4 = V\ CH_4$ cumulated / M VS added. Cumulative CH_4 production over the storage period for one, two or four emptying: $V\ m\ CH_4 = \Sigma\ VCH_4\ (n)$, where n is the day the measurement is recorded and m the number of emptying. If m=1, n=120 days; m=2, n=60 days; m=4, n=30 days.

Calculations and statistical analysis

Data on the volume and composition of the three slurries were obtained from data collected from the animal trial (12 dairy cows) over the four periods of diet tests (Benchaar et al., 2013) and analyzed with diet as main effect in a 4x4 Latin square design using the MIXED procedure of SAS statistical package (SAS release 9.0; SAS institute Inc., Cary, NC). Results from laboratory CH_4 emissions were also analyzed by ANOVA using the MIXED procedure of SAS statistical package in a one-way factorial with diet or bedding as main effect. Each treatment was measure on two separate experimental units (either storage structure or SBRs).

Results

The addition of DDGS30 significantly increased the amount of fresh feces and fresh slurry, DM, VS, N, fat, NDF, ADF and hemicellulose excreted per day and per cow by 11, 15, 18, 18, 8, 70, 30, 15 and 53%, respectively (Table 1). The addition of DDGS10 significantly increased the daily amount of fat in slurry produced by 29% (Table 1). The addition of corn DDGS had no significant (P=0.27) effect on the cumulative fugitive CH_4 emission over the 4-month storage period and the bioenergy production expressed in kg of VS compared to the DDGS0 diet (Tables 2 and 3). However, the daily fugitive CH_4 emission and CH_4 production potential (L $day^{-1}.cow^{-1}$) were increased significantly by 15 (P=0.013) and 14% (P=0.03), respectively, for the slurry from DDGS30 diet (Tables 2 and 3). The addition of wood shavings, straw and peat moss into the 0% corn DDGS slurry significantly reduced (P=0.002) the fugitive CH_4 emissions per kg of VS by 30, 23 and 13%, respectively, compared to DDGS0 (Table 4). However, the addition of wood shavings and straw did not significantly affect the daily fugitive CH_4 emission compared to the DDGS0 diet, contrary to the addition of peat moss which significantly increased (P=0.004) the fugitive CH_4 emission by 27% (Table 4). Regarding manure management, the removal of sludge from the storage tank significantly reduced (P<0.0001) the fugitive CH_4 emission by 96.5% (Table 2) for the average of feeding strategies and 93.3% for the average of bedding types (Table 4). Increasing the emptying frequency reduced the CH_4 emission significantly, i.e. emptying twice over the summer season could reduce the fugitive emission by 42% and emptying 4 times could reduce the emission by 72% (Table 5).

Table 1. Volume and composition of dairy slurry as a function of feeding strategies.

	DDGS$^{\alpha}$0	DDGS10	DDGS30	SEM$^{\beta}$	P-Value
Volume and composition of dairy slurry, kg $day^{-1}.cow^{-1}$					
Slurry	76.1^{b}	80.2^{ab}	84.4^{a}	8.25	0.0026
Feces	51.9^{b}	55.2^{b}	59.8^{a}	11.88	0.0004
Urine	24.3^{a}	24.6^{a}	25.0^{a}	0.34	0.7151
Dry matter	6.85^{b}	7.28^{b}	8.06^{a}	19.59	<0.0001
Volatile solids	5.98^{b}	6.39^{b}	7.05^{a}	19.39	<0.0001
Nitrogen	0.402^{b}	0.413^{ab}	0.434^{a}	3.67	0.0450
Fat	0.433^{c}	0.557^{b}	0.737^{a}	51.79	<0.0001
Neutral Detergent Fiber (NDF)	3.30^{b}	3.55^{b}	4.30^{a}	45.91	<0.0001
ADF	2.00^{b}	2.09^{b}	2.30^{a}	9.70	0.0013
Hemicelluloses	1.31^{b}	1.46^{b}	2.00^{a}	53.31	<0.0001

$^{\alpha}$DDGS: Dried Distillers Grains with Solubles; $^{\beta}$ SEM: Standard Error of the Mean; P-Value for diet effect. Within a row, means with a different subscript letter differ significantly (P<0.05).

Table 2. Fugitive CH_4 emission from manure during the four-months of storage.

	With residual sludge				Without residual sludge						
	DDGS[α]0	DDGS10	DDGS30	SEM[β]	DDGS0	DDGS10	DDGS30	SEM	Diet	Manure Management	Diet* Manure Management
Fugitive CH_4 emission											
L kg^{-1} VS	130.7	125.4	133.1	2.69	5.94	9.31	6.28	0.14	0.5122	<0.0001	0.0657
$L.day^{-1}.cow^{-1}$	165.7	172.3	190.1	2.51	4.61	9.43	6.21	0.19	0.0010	<0.0001	0.0012

[α]DDGS: Dried Distillers Grains with Solubles; [β] SEM: Standard Error of the Mean.

Table 3 Bioenergy production as a function of the feeding strategies

	DDGS[α]0	DDGS10	DDGS30	SEM[β]	P-Value
CH_4 production					
L kg^{-1} VS	255.8[a]	265.0[a]	252.9[a]	1.58	0.3406
$L.day^{-1}.cow^{-1}$	947.5[b]	1054[ab]	1084[a]	13.23	0.0325

[α]DDGS: Dried Distillers Grains with Solubles; [β] SEM: Standard Error of the Mean; P-Value for diet effect. Within a row, means with a different subscript letter differ significantly (P<0.05).

Table 4. Effect of bedding type on manure CH_4 emission during 4 months of storage

	With residual sludge					Without residual sludge							
	No bedding	Wood shaving	Straw	Peat Moss	SEM[β]	No bedding	Wood shaving	Straw	Peat Moss	SEM	Bedding	Manure Managem ent	Bedding* Manure Managem ent
Fugitive CH_4 emission													
L kg^{-1} VS	130.7	91.38	100.9	113.6	2.65	5.94	6.07	5.38	61.4	1.13	<0.0001	<0.0001	<0.0001
L.day-1.cow-1	165.7	163.2	167.1	210.3	4.34	4.61	5.57	4.70	32.6	1.34	<0.0001	<0.0001	0.0572

[β] SEM: Standard Error of the Mean.

Table 5. Effect of manure storage emptying frequency on CH_4 emission over a period of 4 months ($L.day^{-1}.cow^{-1}$).

	1 time	2 times	4 times
DDGS[α]0	165.7	97.9	33.1
DDGS10	172.3	102.2	36.5
DDGS30	190.1	107.9	40.5

[α]DDGS: Dried Distillers Grains with Solubles

Conclusion and perspectives

The inclusion of DDGS in dairy cow diets modified the characteristics of the slurry especially for the addition of 30% of corn DDGS. As a consequence, the daily fugitive CH_4 emission and daily bioenergy production potential (L.day-^{1}.cow-^{1}) were significantly increased by 15 and 14%, respectively, for the slurry from corn DDGS30 diet. The addition of wood shavings and straw did not significantly affect the daily fugitive CH_4 emission whereas the addition of peat moss significantly increased the fugitive CH_4 emission by 27%. The removal of sludge from the storage tank significantly reduced the fugitive CH_4 emission by 96.5% for the average of feeding strategies and 93.3% for the average of bedding types. That present study showed that the frequency of emptying and removal of residual sludge in the manure storage are efficient and easy to adopt BMPs to reduce the fugitive CH_4 emissions. Emptying the tank 2 or 4 times over the summer season could reduce the fugitive CH_4 emission by 42 or 79%, respectively. This project was innovative because it used an integrated approach to assess enteric CH4, manure CH4 and bioenergy recovery related to dairy diets. With such an approach, we make sure that we are not displacing the problem. For example, a new diet formulation that reduces enteric CH4 emission but at the same time substantially increases manure CH4 emission is not recommendable. This project provides scientifically sound and accurate data on the fugitive CH4 emissions from manure storages and on bioenergy recovery potentials from dairy manure in relation to the dairy diet composition and manure management practices. This project proposed cost effective BMPs to substantially attenuate CH4 emission from manure storages. The data from this study will be very useful to increase the accuracy of greenhouse gas calculators and of life cycle analysis for different farm management practices (diet composition, manure management, bioenergy recovery, etc.).

References

[1] Kebread, E., Clark, K., Wagner-Riddle, C. and France, J., 2006. Methane and nitrous oxide emissions from Canadian animal agriculture: A review. Canadian Journal of Animal Science 86, 135-158.

[2] Husted, S., 1994. Seasonal variation in methane emission from stored slurry and solid manures. Journal of Environmental Quality 23, 585-592.

[3] Khan, R.Z., Müller, C., Sommer, S. G., 1997. Micrometeorological mass balance technique for measuring CH4 emission from stored cattle slurry. Biological and Fertility of Soils 24 (4), 442-444.

[4] Massé, D. I., Masse, L., Croteau, F., 2003. The effect of temperature fluctuations on psychrophilic anaerobic sequencing batch reactors treating swine manure. Bioresource Technology 89, 57-62.

[5] Dinuccio, E., Berg, W., Balsari, P., 2008. Gaseous emissions from the storage of untreated slurries and fractions obtained after mechanical separation. Atmospheric Environment 42, 2448-2459.

[6] McGinn, S.M., Y.-H. Chung, K.A. Beauchemin, A.D. Iwaasa, and C. Grainger. 2009. Use of corn distiller's dried grains to reduce enteric methane loss from beef cattle. Can. J. Animal Sci. 89:409-413.

[7] Jarret, G., P. Cozannet, J. Martinez, and J.Y. Dourmad. 2011. Effect of different quality wheat dried distiller's grain solubles (DDGS) in pig diets on composition of excreta and methane production from faeces and slurry. Livestock Science. 140:275-282.