Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

Optimizing feed and manure management to reduce methane and nitrous oxide emissions from livestock manure storage and composting

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Canada

Introduction

- Globally, the agriculture sector contributes 12-14% of greenhouse gas (GHG) emissions
- The livestock production contributes approximately 11% of GHG emissions in Canada, mainly in the form of CH_4 and N_2O
  - 8% from enteric fermentation
  - 3% from manure management
- Canada is committed to reducing GHG emissions and livestock industry must play a role

Livestock operations

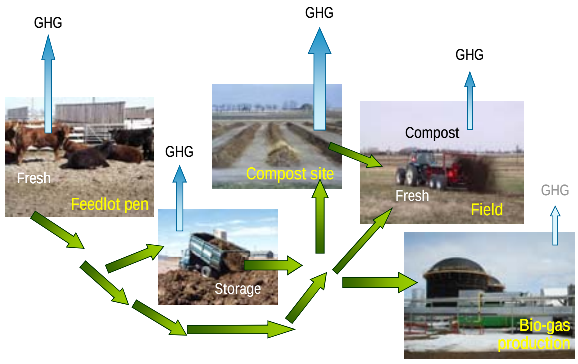
- Current trend is towards large confined operations
  - Produce huge quantities of manure
  - Apply it to a small land area
- Alberta has 6.6M cattle (43% of the national herd)
  - County of Lethbridge licensed feedlot capacity: ~750,000 head
  - Several feedlots >25,000 head
- Manure is disposed of rather than used as fertilizer for crop production
- Manure management is a major environmental issue

Objective:

- Review CH_4 and N_2O emissions from livestock manure and suggest possible mitigation strategies

Feedlot manure handling

Greenhouse gas emissions from livestock manure



GHG emissions from livestock manure

Mitigation strategies

- Diet manipulation
- Animal production management
- Manure storage
- Composting
- Land application
- Bio-energy production

8

Processes controlling CH_4 emission

- CH_4 emission influenced by:
  - production (methanogens)
  - consumption (methanotrophs)
  - pathways to emitting surface
- CH_4 production increases with:
  - Rich organic matter substrate
  - Lack of oxygen
  - Redox potential below – 200 mV
  - Near neutral pH
  - Sufficient nutrients (N, P, K, S)
  - Electron acceptors such as NO_3

(Conrad, 1989)

Processes controlling N_2O emission

- Nitrification and denitrification
  - Nitrification requires NH_4^+, O_2
  - Denitrification requires NO_3^- and anaerobic conditions
- Affected by:
  - aeration
  - available N
  - pH
  - moisture
  - soluble C
  - C/N ratio
  - temperature

Diet manipulation

- Why?
  - Improve feed efficiency
  - Produce better end product
  - Control cost of feedstuff
- How?
  - Protein, amino acid, dry matter intake
  - Fibre level
  - Enzymes
  - Phase feeding
  - Feed supplement and additives

Diet manipulation

- Effects on manure properties:
  - C and N concentrations
  - inorganic vs. organic forms and proportions
  - pH
  - soluble C
  - C/N ratio
  - volatile fatty acids (VFA)
- These in turn affect GHG emissions

Diet manipulation - examples

- Concentrate supplement
  - decreased enteric CH_4 emission (18%)
  - increased CH_4 emission from slurry storage
  - net reduction: 12% *(Hindrichsen et al., 2006)*
- Forage type in dairy cow diet
  - no effect on N_2O and CH_4 emissions during manure storage *(Külling et al., 2003)*
- High dietary crude protein (N)
  - more N_2O production, but lowest CH_4 emission from manure storage *(Külling et al., 2001)*
- Shac® natural feed additive in beef cattle finishing diet
  - did not affect CO_2, N_2O or CH_4 emissions from manure
  - reduced NH_3 emission *(Hao et al., 2007)*

13

GHG emission from soil – effects of sheep diet type

		Diet type			Control
	Parameter	Ryegrass	Lucerne	Kale	soil*
Slurry	Solid (%)	6.4	8.1	5.9	
	TN (%)	0.24	0.77	0.34	
	NH_4-N (%)	0.087	0.498	0.201	
	C/N ratio	11.7	4.0	5.8	
N_2O	Aerobic (32 d, kg/ha)	2.16	3.14	6.98	0.70
	Anaerobic (4 d, kg/ha)	0.05	0.09	0.32	0.08

*Control soil: no slurry applied
Soil characteristics: pH 7.1; BD: 1.22 g/cm^3; NO_3-N: 4.9 mg/L; NH_4-N: 3.1 mg/L

(Cardenas et al., 2007)

14

Animal production facilities

- Open facility
  - Bedding material
  - Frequency of pen cleaning
- Closed housing
  - Ventilation
  - Slotted floor vs. deep litter
  - Aeration (liquid manure)

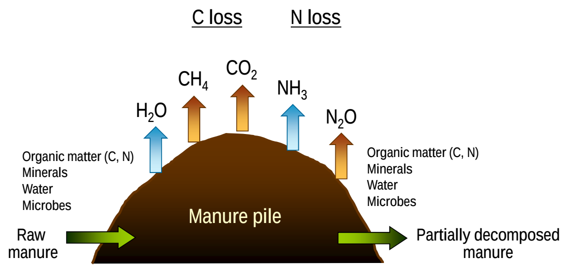
15

Animal facilities – mitigating GHG emissions

- Swine fattening facility
  - fully slotted floor vs. deep litter system
  - lower N_2O emission; similar CH_4 emission *(Philippe et al., 2007)*
- Swine fattening facility
  - straw flow system vs. force ventilation fully slotted floor system
  - lower N_2O and CH_4 emissions *(Amon et al., 2007)*
- Laying hens facility
  - droppings dried on ventilated belt vs. prolonged in-house deep-pit storage
  - lower CH_4 emission, but similar N_2O emission *(Fabbri et al., 2007)*
- Manure temperature
  - cooling manure (<10ºC) reduces CH_4 production from animal housing *(Monteny et al., 2006)*

16

Manure storage



17

GHG emissions during manure storage

Manure management options

- Liquid manure
  - Covering
  - Solid and liquid separation
  - Dilution
  - Aeration
  - Chemical amendments
    - pH
    - Staloson®, Biosuper®
- Solid manure
  - Bedding material
  - Amendment
  - Covers
  - Compaction

18

Covering solid manure during storage

- Separated solids from bio-digested swine manure slurry
  - Covered vs. non-covered; 4 months of storage
  - CH_4 emission reduced by 87%; N_2O emission reduced by 42%

(Hansen et al., 2006)

- Beef cattle manure
  - Covering and compacting reduces N_2O emission
  - Extent of reduction dependent on stage of storage *(Amon et al., 2007)*

19

Liquid manure management

- Swine lagoon
  - pull-plug system (1-week cycle) vs. periodic flush
  - lower CH_4 emission *(Sharpe et al., 2002)*
- Liquid manure
  - covering with straw increases N_2O and CH_4 emissions *(Berg et al., 2006)*
- Swine slurry
  - covering or reducing slurry pH reduces GHG emissions *(Amon et al., 2007)*
- Stored swine slurry
  - dilution and using additives such as NX23®, Staloson® and Biosuper® reduces CH_4 emission *(Martinez et al., 2003)*

20

GHG emissions from dairy slurry

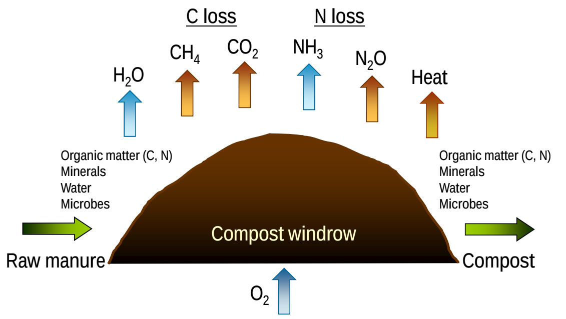
	Untreated	Separated	Digested	Straw cover	Aerated
Storage (80 d)	91.21*	41.29	37.03	119.03	51.64
Storage – solid fraction		14.81			
Field application (20 d)	1.19	2.40	0.86	3.67	1.68
Total emissions	92.40	58.50	37.89	119.73	53.32
Storage / total (%)	98.7	95.9	97.7	96.9	96.8
Field / total (%)	1.3	4.1	2.3	3.1	3.2

*Expressed as kg CO_2 eq. m^{-3} slurry *(Amon et al., 2006).*

For both swine and cattle manure slurries, separating did not affect CH_4 or N_2O emissions, but increased CO_2 emission. Slurry from swine emits more GHG than does slurry from cattle. *(Dinuccio et al. 2008)*

21

Composting



22

Composting

- Types of composting operations
  - Open window
  - Forced aeration
- Options for reducing GHG emissions
  - Manure properties

    (bulking material to adjust C/N ratio and moisture content)
  - Pile dimensions
  - Aeration
  - Amendments

23

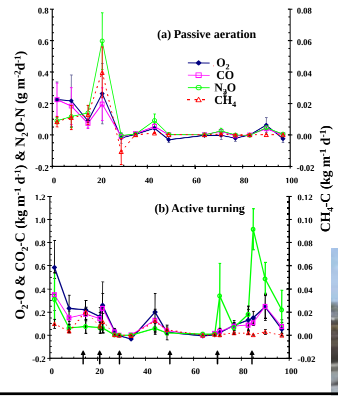
Feedlot manure composting and GHG studies at LRC*

Year	Comparison
1997	Aeration: passive vs. active
1999	Bedding material: straw vs. wood chips
2002	Added phosphogypsum vs. control
2004/05	Dietary antibiotics vs. control
2005	Cattle mortalities vs. manure only
2006	Cattle vs. specified risk materials (SRM)
2007	Dietary dried distillers' grains with solubles (DDGS) vs. control

*AAFC Lethbridge Research Centre

24

Aeration: passive vs. frequent turning



Composting and GHG emissions

- Solid swine manure
  - Adding nitrite-oxidizing bacteria reduces N_2O emission *(Fukimoto et al., 2006)*
- Manure piles
  - Adding straw reduces CH_4 and N_2O by increasing C/N ratio *(Yamulki, 2006)*
- Manure amendments
  - C-rich amendments (e.g., straw, wood chips) reduces N_2O emissions *(Mahimairaga et al., 1995)*
- Compost amendment
  - Adding phospho-gypsum reduces CH_4 emission *(Hao et al., 2005)*

Composting and GHG emissions

- Compost pile size
  - Larger piles increases CH_4 and N_2O emissions due to poor aeration *(Fukumoto et al., 2003)*
- Aeration
  - Forced aeration and turning reduces CH_4 emission *(Lopez-Real and Baptista, 1996)*
- Compost pile porosity
  - Higher porosity reduces N_2O emission *(Sommer and Moller, 2000)*
- Bedding material for feedlot cattle
  - In open windrow composting, no differences in GHG emissions from manure between straw bedding and woodchip bedding *(Hao et al., 2004)*

Land application of manure – N_2O emissions

- Manure applied
  - Type of livestock manure
  - Total and available C, N content
  - C/N ratio
  - Moisture content
- Soil physical properties
  - Moisture
  - Texture
  - Porosity
- Tillage and irrigation
- Emissions from soil are higher with livestock manure than with mineral fertilizer *(Bhandral et al., 2007)*

Summary

- Strategies can reduce C and N content in manure (e.g., diet manipulation) and retain nutrients and reduce GHG emissions (e.g., manure management)
- Research must consider the entire cycle of GHG generation, including diet formulation, animal metabolism, storage and treatment of excreta, and field application of manure
- Mitigating GHG requires an integrated perspective
- Agronomic, economic, environment, health and safety, social and technical factors must be considered

Current GHG and manure management research

- Produce H_2 energy from cattle feedlot manure
- GHG emission from soil receiving different bio-fertilizers (fresh vs. bio-digested cattle feedlot manure)
- Impact of DDGS feed on cattle manure properties and subsequent GHG emission during manure storage and composting