24 Oct 2019

IEA Bioenergy Task 37 Business Meeting Joint Workshop
COEX Hall E3, Seoul, South Korea

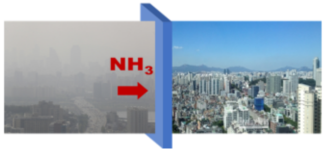
Keep manure fresh, get more !

Odor

GHGs

Renewable energy

Particulate matter



Dong-Hoon Kim, Seongwon Im

Department of Civil Engineering,
Inha University, South Korea

dhkim77@inha.ac.kr

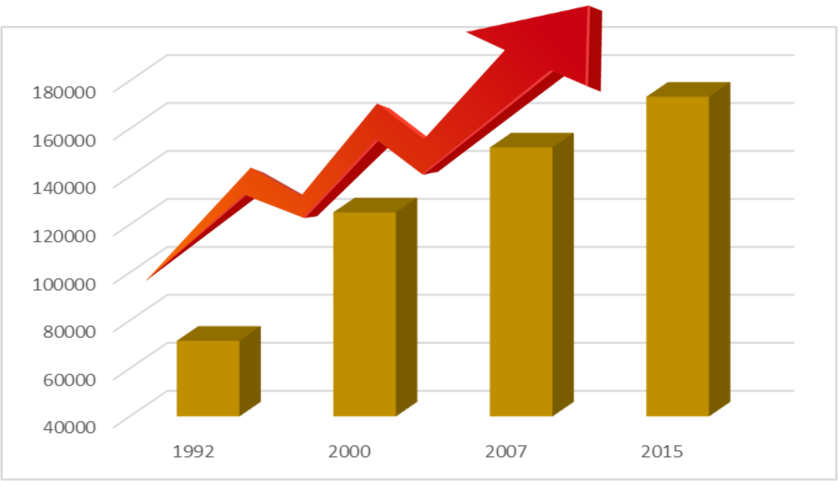
인하대학교
INHA UNIVERSITY

IEA Bioenergy

Introduction (1)

- **Livestock manure production in Korea**

  - Population growth
  - Increase in meat consumption
  - 17,000 ton/d in 2017



-MOE, Statistic livestock manure treatment 2015

- **Livestock manure treatment status in Korea**

Wastewater treatment (8.3 %)

Etc. (2.7%)

Composting (89.0%)

  - Lots of electrical energy consumption
  - Odors and environment pollutants emissions

- MOE, White paper of environment 2016

Introduction (2)

Index	Water content (%)	VS content (VS/TS, %)	COD /VS	Theoretical maximum* (m^3/ton)	Digestion efficiency (%)	Practical value (m^3/ton)	Waste generation (10^6 ton/y)	Biogas Production (10^6 m^3/y)
Food waste	83	95	1.3	147	70	103	5.6	576
Sewage sludge (cake)	80	90	1.3	164	50	82	3.8	315
Livestock waste	90	90	1.3	82	40	33	63.3	2,072

* Theoretically, 1 kg COD = 0.35 m^3, CH_4 = 0.7 m^3 biogas (CH_4 = 50%)

Food waste → 1 ton × 1,000 kg/ton × 0.17 × 0.95 × 1.3 × 0.7 m^3 biogas

2,963 × 10^6 m^3 = 1,482 × 10^6 m^3 CH_4 = 54,075 × 10^6 MJ = 12,924 × 10^6 Mcal

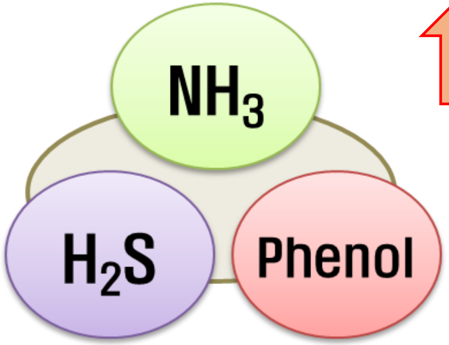
= 1,292,387 TOE

(<0.5% total primary energy supply in Korea 2016) (36.5 MJ/m^3 CH_4, 1 TOE: 10^7 kcal)

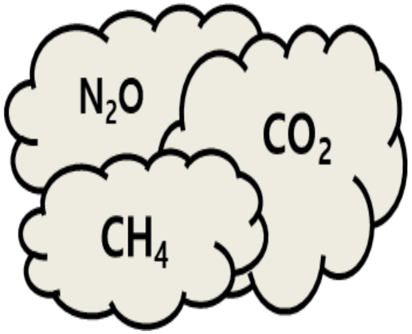
Introduction (3)

<Storage time>
1-6 months

Odor emission



GHGs emission



Water contamination

Low quality compost

Introduction (4)

Summer | **Winter**

Bedding materials

- sawdust, husk
- changed frequently during winter (once/month)
- there is no standard for changing (but when cow is coated with feces)
- 500-2,000 USD/month/100 cow

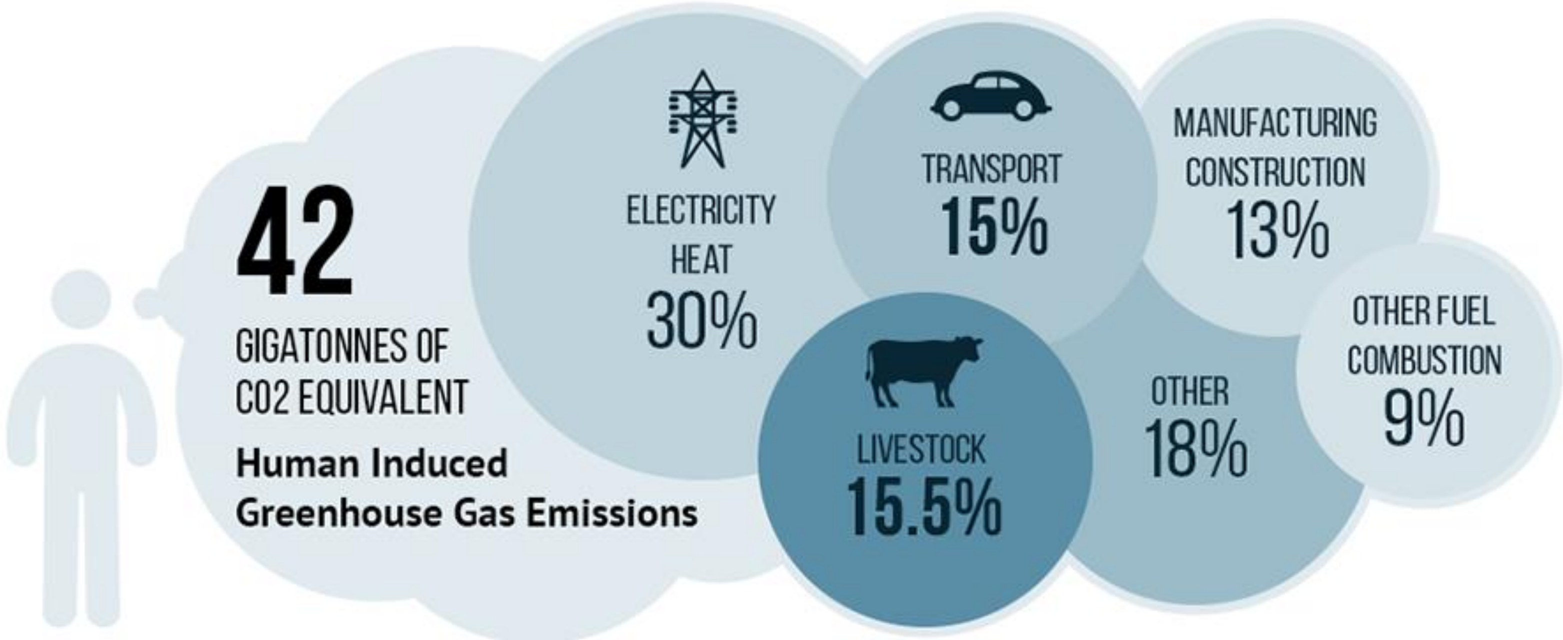
Cow house

- Volume reduction of cow manure
- Summer: dried condition
- Winter : wet condition
- Odor problem was significant both in summer and winter

Compost storage field

- Stored for 1-3 months

Introduction (5)



- FAO, EDGAR, and World Resources Institute

4.2 Million ton CO_2 eq./y

Intestinal fermentation

4.6 Million ton CO_2 eq./y

Storage **Treatment**

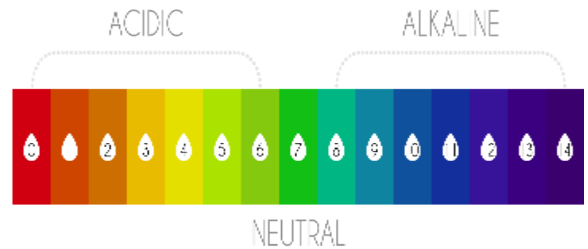
- Ministry of Environment, South Korea, 2017

Introduction (6)

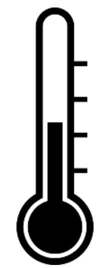
- Bacteroidetes
- Firmicutes
- Proteobacteria
- Verrucomicrobia
- Methanogens

Microorganisms

Influential factors



pH value



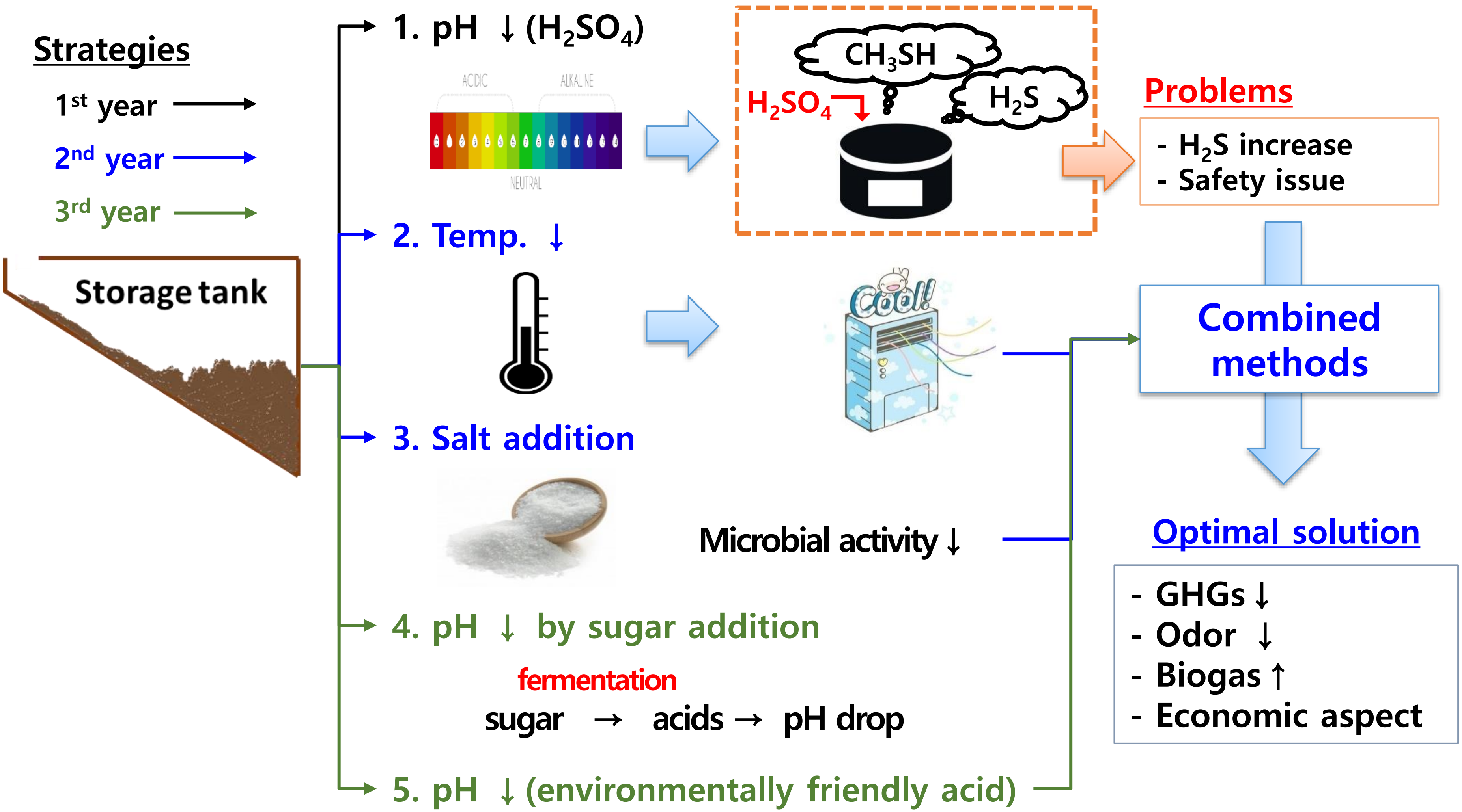
Temperature

Water content

- Research objectives

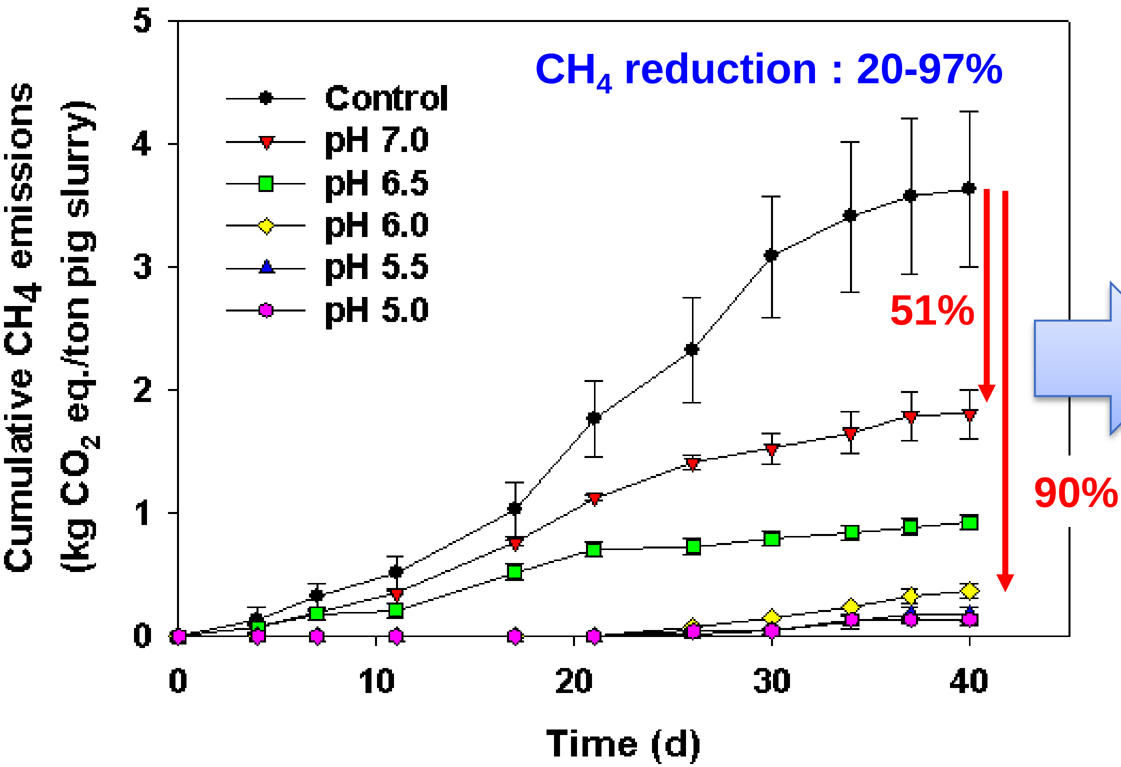
- ➢ **Develop CH_4 emission reducing methods in lab-scale experiments**
- ➢ **Apply to pilot-scale plant**
- ➢ **Effects on odor and biogas production**

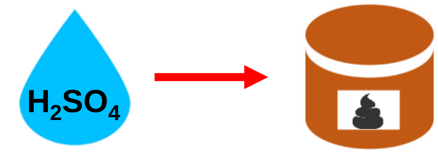
Reducing Strategies



Results & Discussion (1)

- **Acidification of PS (pH control, H_2SO_4 addition)**





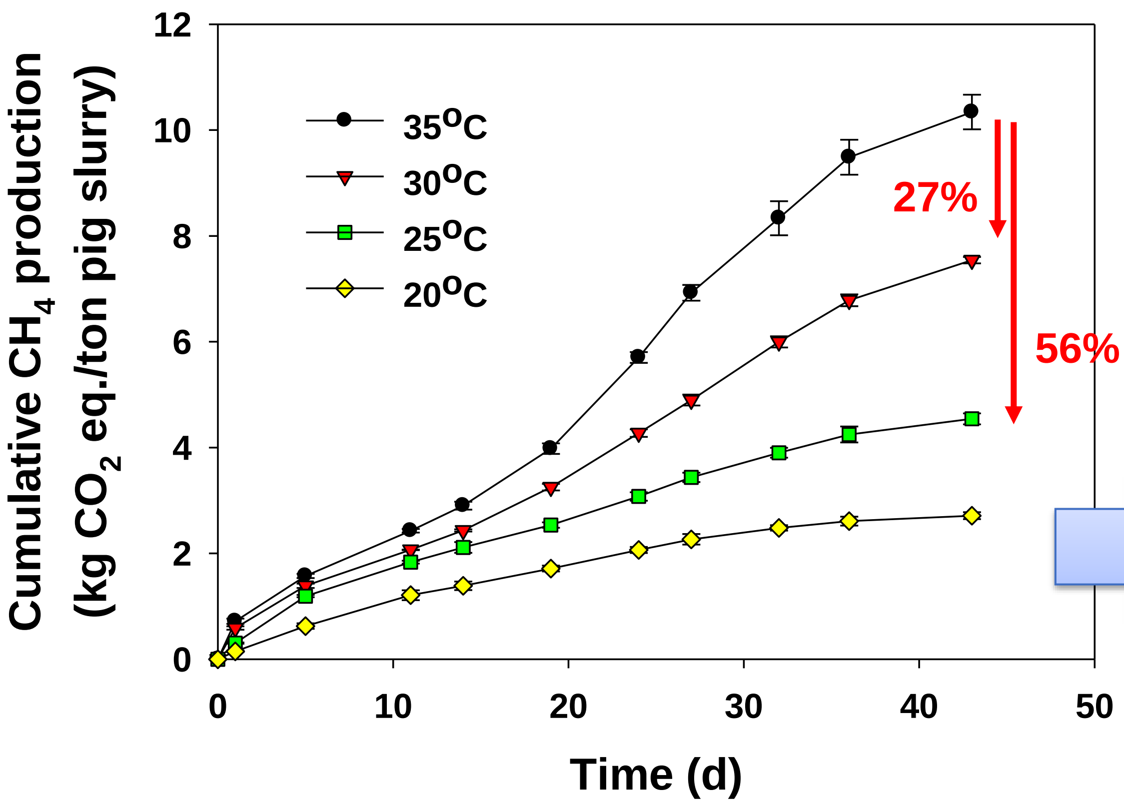
- Characteristic of fresh and acid-treated PS

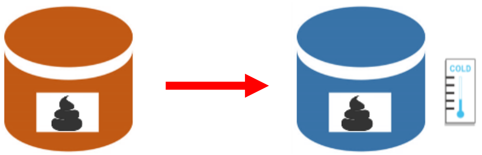
40 d of storage	VS (g/L)	COD (g/L)
Fresh PS	35.9	76.3
Control	25.5	53.4
pH 7.0	29.8	61.8
pH 6.5	30.2	63.5
pH 6.0	30.9	66.5
pH 5.5	33.8	72.9
pH 5.0	32.7	72.3

	Control	pH 7.0	pH 6.5	pH 6.0	pH 5.5	pH 5.0
Sulfuric acid (95%) addition (mL/L PS)	-	0.4	1.3	2.7	3.5	6.0
CH_4 emission (kg CO_2 eq./ton PS)	3.7	1.8 (51%)	1.0 (73%)	0.4 (90%)	0.2 (95%)	0.1 (97%)

Results & Discussion (2)

- **Temperature control of PS**





- Characteristic of fresh and stored PS

45 d of storage	VS (g/L)	COD (g/L)
Fresh PS	58.4	104.2
35°C	37.9	68.5
30°C	43.9	76.2
25°C	50.1	83.4
20°C	54.2	95.5

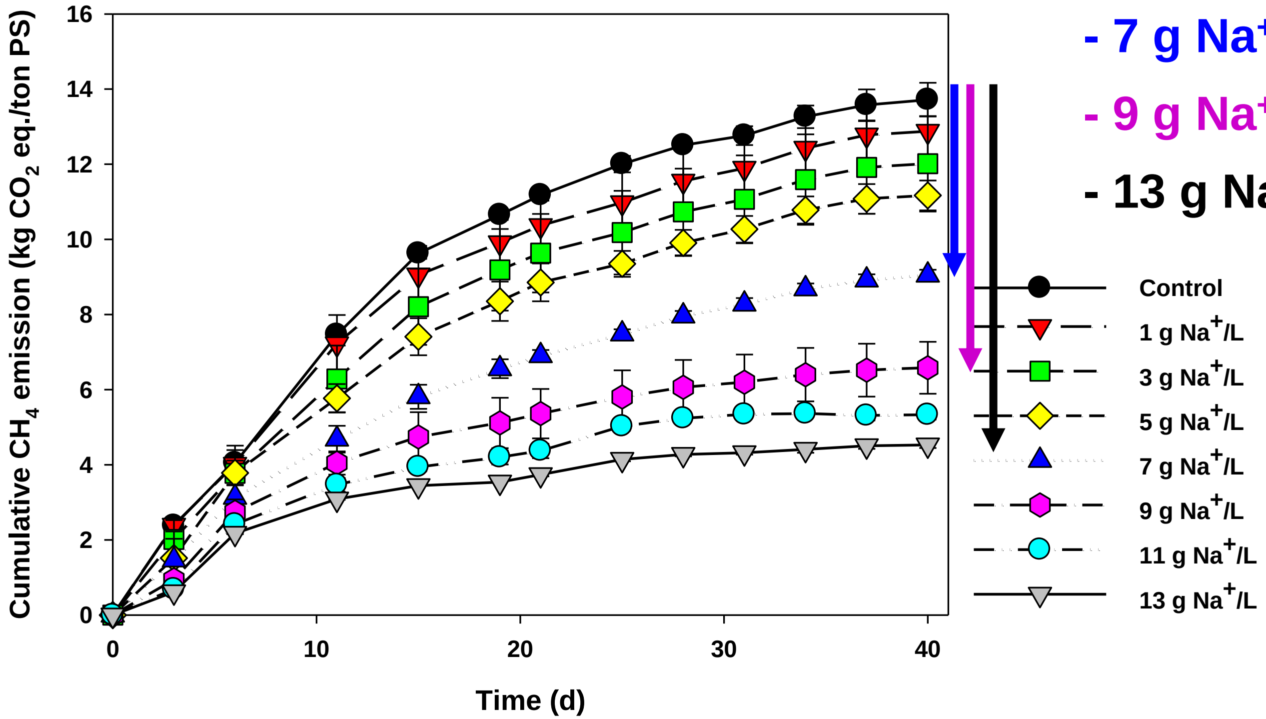
→ **CH_4 reduction : 56% (35°C → 25°C)**

: 10.3 → 4.5 kg CO_2 eq./ton PS

→ **Inhibition of organic matter degradation**

Results & Discussion (3)

- **Salt addition**



- 7 g Na^+/L : 9.0 (34%)

- 9 g Na^+/L : 6.6 (52%)

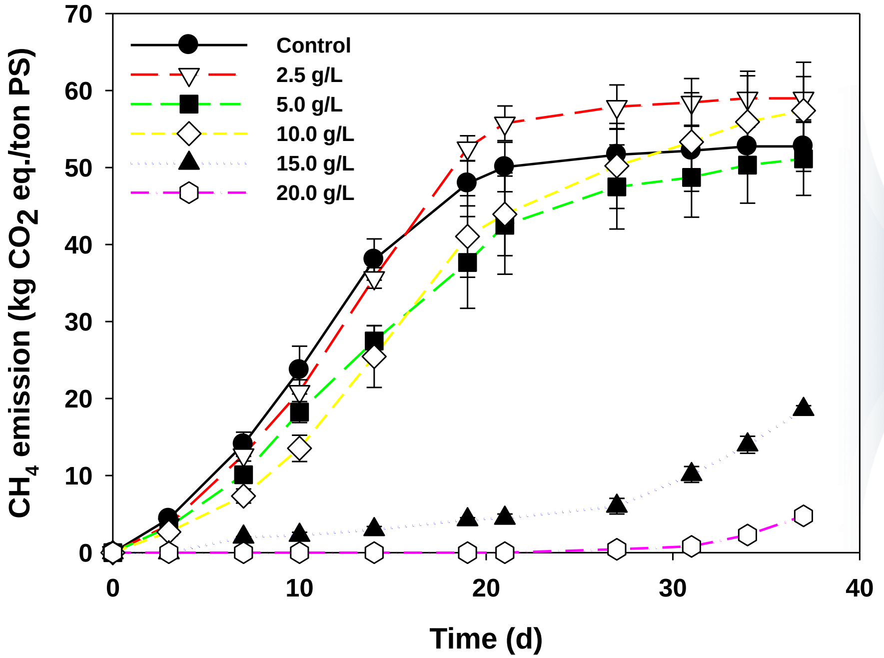
- 13 g Na^+/L : 4.5 (67%)

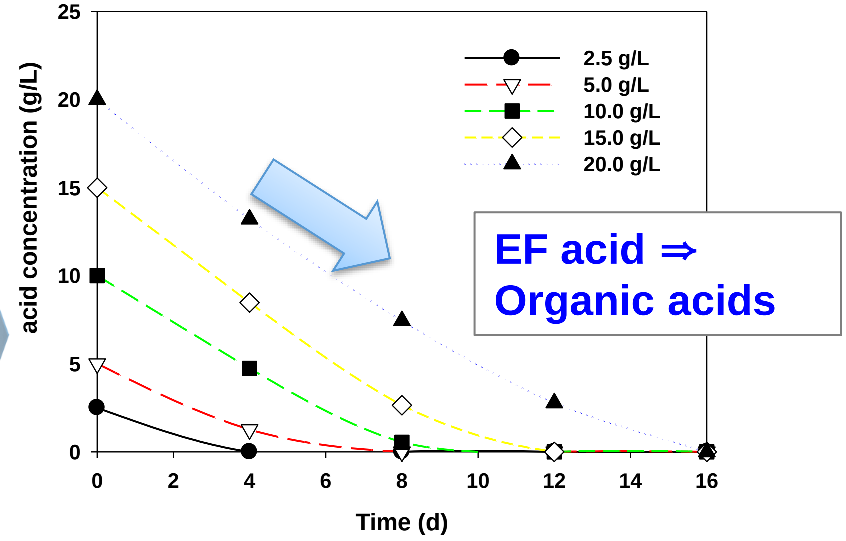
→ 50% reduction : 9 g Na^+/L

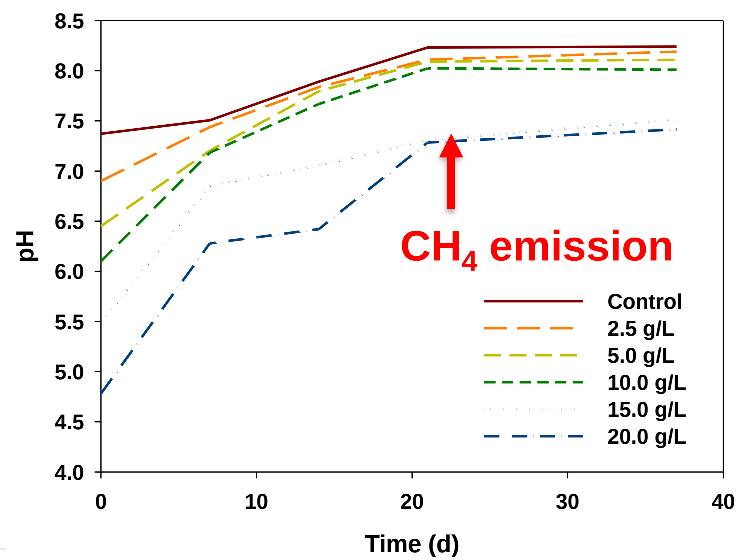
	Control		Na^+ conc. (g Na^+/L)						
	Fresh	**Storage**	**1**	**3**	**5**	**7**	**9**	**11**	**13**
TS (g/L)	107.7	58.4	61.6	68.3	75.5	84.0	91.1	95.0	100.3
VS (g/L)	71.4	36.1	38.3	38.9	40.4	43.0	44.5	44.1	45.5
COD (g/L)	**109.7**	65.7 **(40%↓)**	68.4 **(38%↓)**	71.8 **(35%↓)**	72.4 **(34%↓)**	77.6 **(29%↓)**	81.8 **(25%↓)**	83.9 **(24%↓)**	86.5 **(21%↓)**

Results & Discussion (4)

- **Acidification of PS (EF acid addition)**





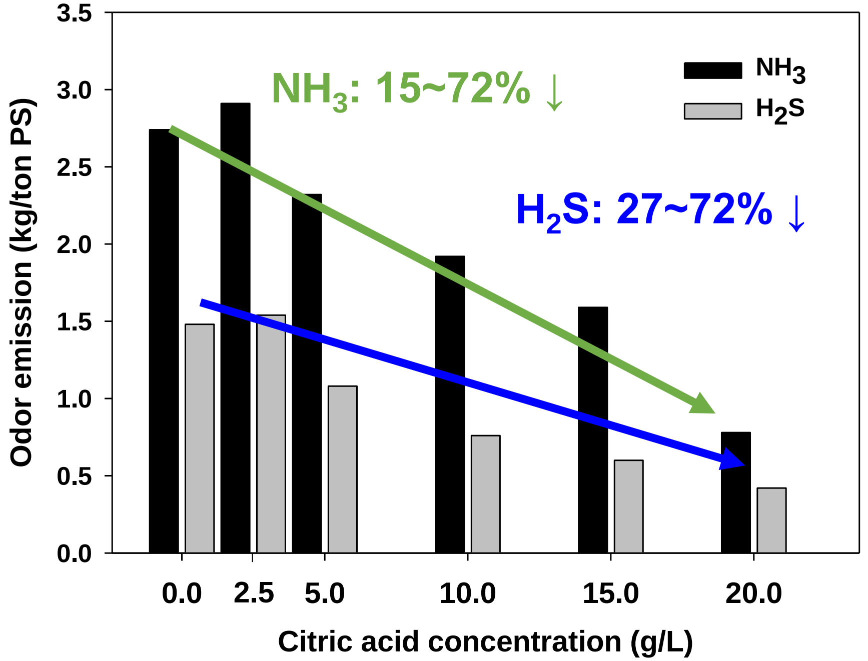


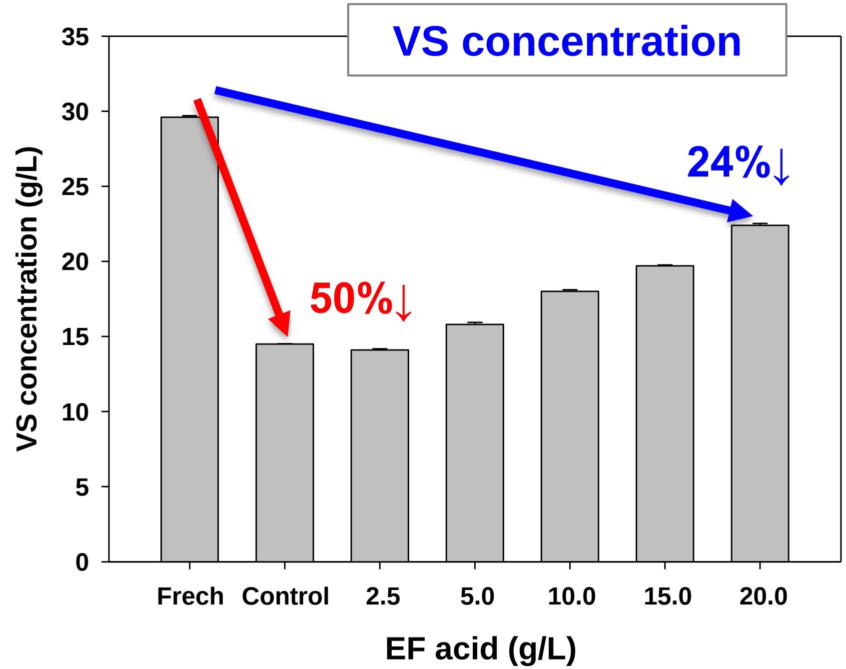
(kg CO_2 eq./ton PS)

Control (pH 7.4)	EF acid concentration (g/L)				
	2.5 (pH 6.9)	5.0 (pH 6.5)	10.0 (pH 6.1)	15.0 (pH 5.5)	20.0 (pH 4.8)
52.7 ±3.2	59.0 ±2.8 (+12%)	51.1 ±4.7 (+3%)	57.4 ±6.3 (+9%)	18.6 ±0.5 (-65%)	4.8 ±0.4 (-91%)

Results & Discussion (5)

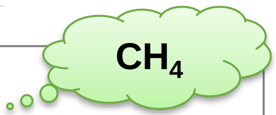
- **Acidification of PS (pH control, EF addition)**





(kg/ton PS)

	Control (0.0 g/L)	EF acid concentration (g/L)				
		2.5	5.0	10.0	15.0	20.0
NH_3	2.7	2.9	2.3	1.9	1.8	0.8
H_2S	1.4	1.5	1.1	0.8	0.8	0.4



Biogas(CH_4) Production*

Control: 3.6 m^3 CH_4/ton

20 g/L: 5.6 m^3 CH_4/ton

55% ↑

*CH_4 yield: 0.25 L CH_4/g VS

Results & Discussion (6)

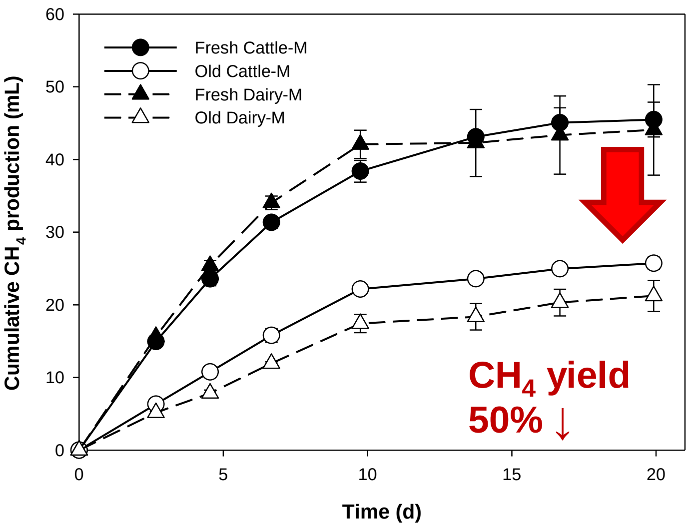
	Cow manure (CM)		Dairy manure (DM)	
	Fresh	Old	Fresh	Old
Total solid (%)	16.7	39.2	14.1	49.2
Volatile solid (%)	**14.3**	**24.5**	**12.5**	**35.9**
COD (g/L)	234.1	398.4	207.7	532.1

	Fresh	Old
CM		
DM		

BMP test

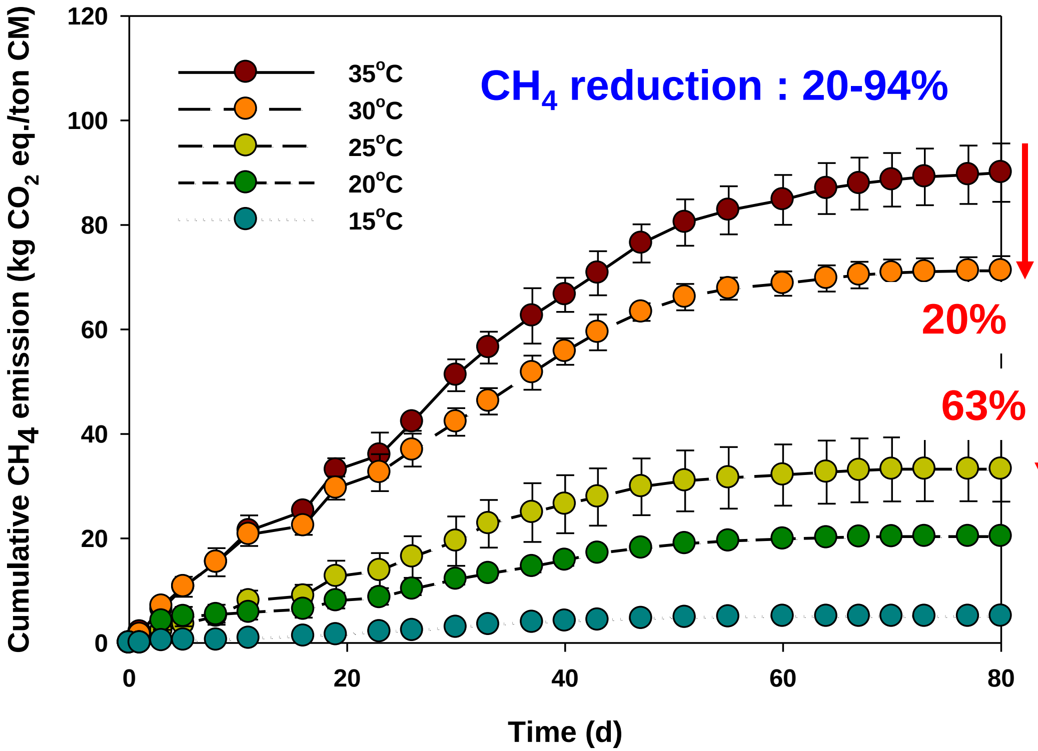
		CH_4 yield			
		mL CH_4/g TW*		mL CH_4/g VS	
CM	Fresh	28.4	≒	198.9	>
	Old	26.8		109.2	
DM	Fresh	23.7	<	189.1	>
	Old	34.2		95.5	

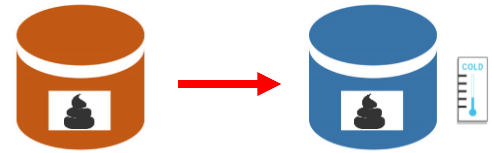
*TW: total weight



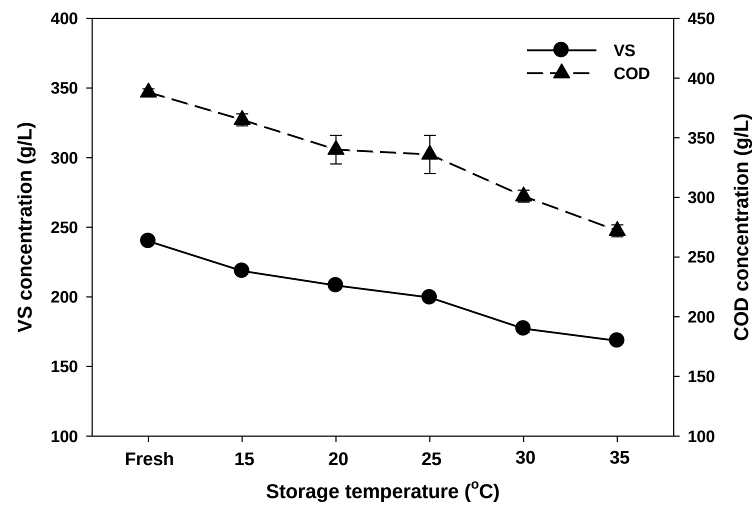
Results & Discussion (7)

- **Temperature control of CM**





- VS and COD concentration of fresh and stored CM



→ CH_4 reduction : 62% (35°C → 25°C)

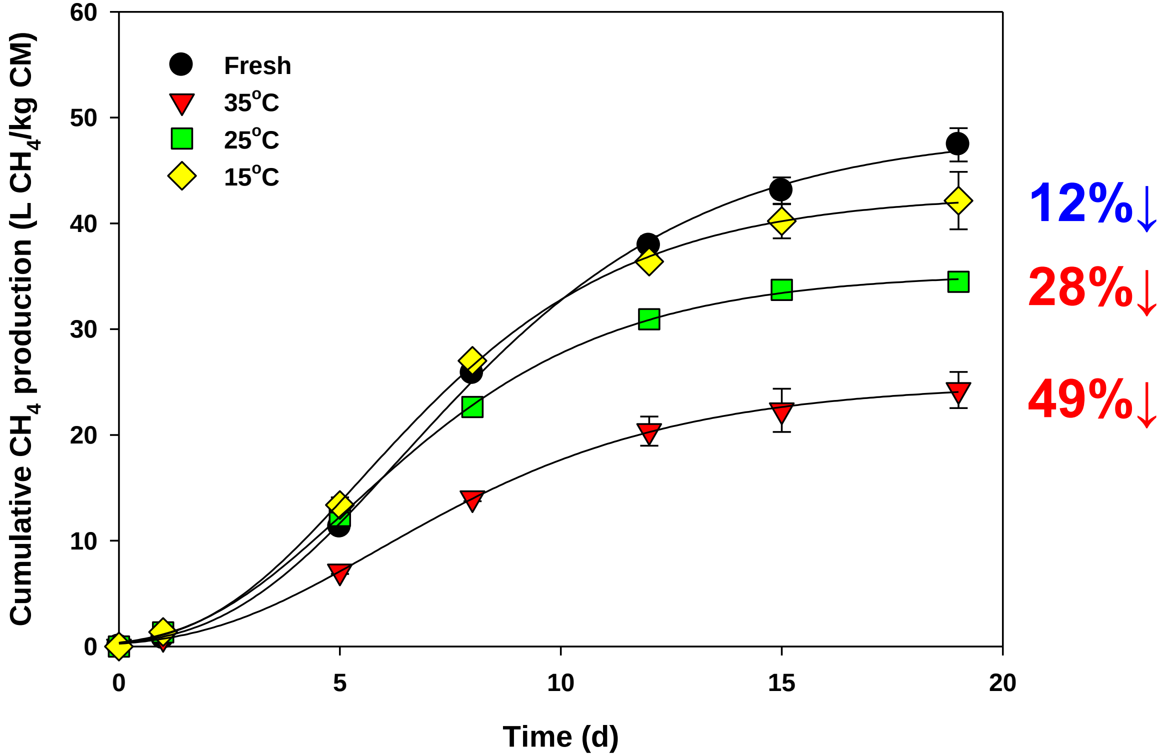
: 90.0 → 33.3 kg CO_2 eq./ton CM

→ Inhibition of organic matter degradation (35°C vs 25°C)

: 270 vs 365 g COD/L

Results & Discussion (8)

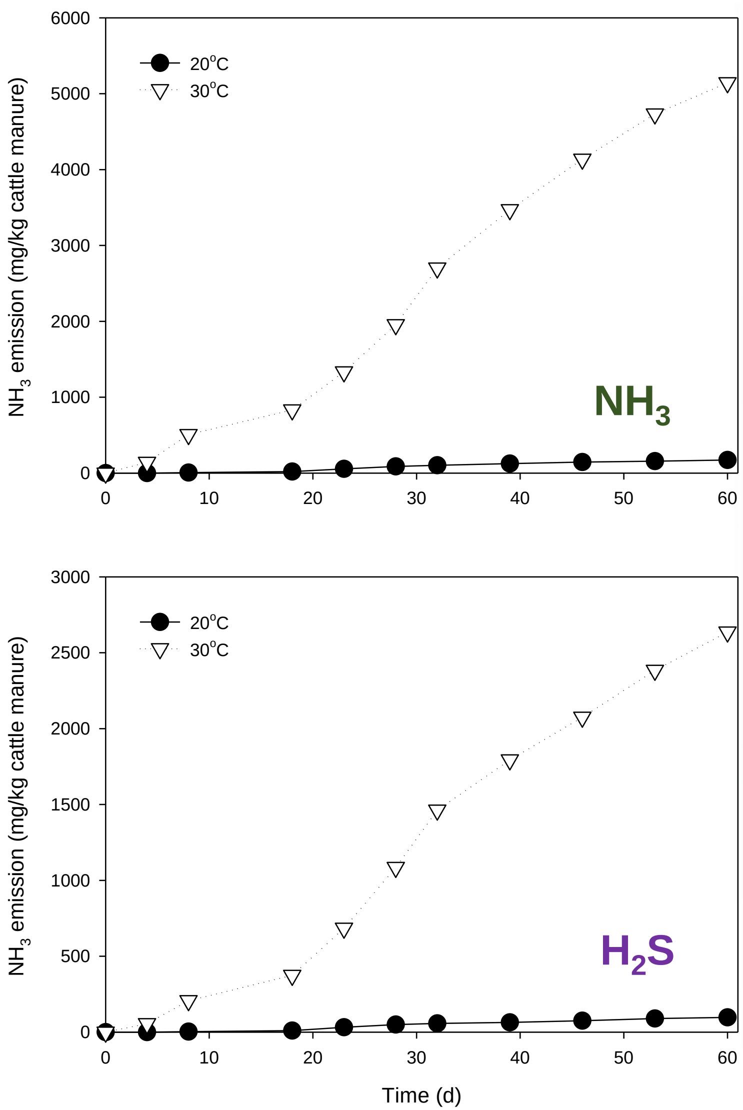
- CH_4 potential of stored CM

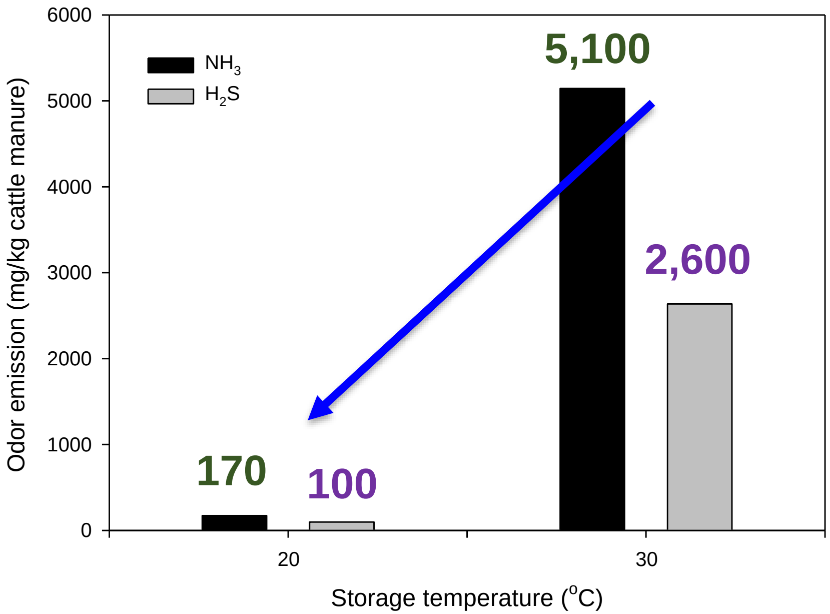


		Fresh	15°C	25°C	35°C
CH_4 production	L CH_4/kg CM	48.8	42.8	35.3	24.9
	L CH_4/g VS	197.6	195.7	177.1	147.5

Results & Discussion (9)

- **Reduction of odor emissions**





Temp.	Odor (ppm)	
	NH_3	H_2S
20^{o}C	3.6-20.0 (average: 8.6)	1.8-12.0 (average: 4.9)
30^{o}C	73.6-427.4 (average: 247.1)	28.8-210.4 (average: 126.4)

Acknowledgements

환경부

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