Comparing the performance of common ammonia stripping configurations for enhancing the biogas potential of poultry manure

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Problem Statement

World meat production of cattle (including buffalo), sheep (including goats), poultry, and pork from 1961 to 2014 (Million t; Michalk et al., 2019).
Problem Statement

348 Million Headcount (Canada)
Most widely available livestock

120 kg manure per 1000 layer chicken
About 15.2 Million tons per year (Canada)

World meat production of cattle (including buffalo), sheep (including goats), poultry, and pork from 1961 to 2014 (Million t; Michalk et al., 2019).
Problem Statement - Current Management

Land Application

- Advantages
  - Good fertilizer
  - Cheap and widely available

- Disadvantages
  - High methane emissions
  - Eutrophication
  - Smell & Odor
  - No energy generation

Composting

- Advantages
  - Valuable product for agriculture or household
  - Stabilized waste
  - Controlled emissions

- Disadvantages
  - Smell & Odor
  - Energy consumption
  - No energy generation
Anaerobic Digestion – Ammonia inhibition

Proteins and urea → Ammonia

Hydrolysis  Acidogenesis  Acetogenesis  Methanogenesis

Anaerobic Digestion Stages

[Diagram showing the stages of anaerobic digestion and the inhibition caused by ammonia]

[Images of animals indicating the inhibition process]
Ammonia Stripping

- **NH\textsubscript{3}**
- **Carrier gas**
- **Ammonia stripping column**
- **Gas meter**
- **Carrier gas source**
Ammonia Stripping

1- Increase pH

Limestone (Calcium hydroxide)

2- Increase temperature

Heat source

3- Gas flowrate

Gas meter

4- Gas type

Carrier gas source

5- Duration of Stripping

NH₃

Carrier gas

Ammonia stripping column
Ammonia Stripping Configurations

**Side-stream (SSAS)**
- Anaerobic Digester
- Ammonia stripping column
- Most common method
- Targets high-ammonia levels
- Low energy demand
- Requires solid/liquid separation to minimize microorganisms shock
- Carrier gas selection is often restricted

**Post-hydrolysis (PHAS)**
- Hydrolyzer
- Ammonia stripping column
- Most recent advancement
- Targets high-ammonia levels
- Low energy demand
- No solid/liquid separation
- Carrier gas selection is flexible
Study Objectives

- Compare the performance of PHAS and SSAS under similar ammonia stripping conditions
- Test PHAS in semi-continuous mode for the first time
- Test RNG as a stripping medium in semi-continuous mode for PHAS and SSAS
- Provide high-nitrogen organic waste producers with more sustainable treatment options
Methodology

**Stripping medium**

**Post-hydrolysis Ammonia Stripping (PHAS)**
- Hydrolyzer
  - Ammonia stripping column
  - Air
    - Anaerobic Digester
    - RNG
      - All hydrolysis effluent (5% digester volume per day)

**Side-stream Ammonia Stripping (SSAS)**
- Anaerobic Digester
  - Ammonia stripping column
  - RNG
    - 20% digester volume per day
    - Air
      - 10% digester volume per day
      - 10% digester volume per day

**Treatment portion**

- All hydrolysis effluent (5% digester volume per day)
- All hydrolysis effluent (5% digester volume per day)
- 20% digester volume per day
- 10% digester volume per day

**Control scenario**
- Conducted at the end
- No treatment
- Baseline to evaluate biogas enhancement
Methodology

5 L semi-continuous hydrolysis reactors
10 L working volume

Ammonia stripping column with hot water recirculation system

15 L semi-continuous Biogas reactors
10 L working volume
Results: Semi-continuous CSTR Biogas Production

Inoculation

Inoculum → Anaerobic Digester

Inoculation

TAN Levels 709 mg/L

Biogas Production

Enhancement to Control/Blank
Results: Semi-continuous CSTR Biogas Production

Startup Phase

Diluted (low TAN) PM → Anaerobic Digester

**Start-up**

**TAN Levels** 1000 mg/L

**Biogas Production** 600 L biogas/kg VS.day

**Enhancement to Control/Blank** N/A

Figure 7-2
Results: Semi-continuous CSTR Biogas Production

Post-hydrolysis Ammonia Stripping (PHAS)

Hydrolyzer → Anaerobic Digester

Air → Ammonia stripping column

PHAS-I (Air)

- TAN Levels: 1800 mg/L
- Biogas Production: 830 L biogas/kg VS.day
- Enhancement to Control/Blank: 432%
Results: Semi-continuous CSTR Biogas Production

Post-hydrolysis Ammonia Stripping (PHAS)

RNG

Hydrolyzer → Post-hydrolysis Ammonia Stripping column → Anaerobic Digester

PHAS-2 (RNG)

TAN Levels: 2484 mg/L

Biogas Production: 680 L biogas/kg VS.day

Enhancement to Control/Blank: 336%
Results: Semi-continuous CSTR Biogas Production

Side-stream Ammonia Stripping (SSAS)

- Anaerobic Digester
- RNG (20%)
- Ammonia stripping column

SSAS-I (RNG at 20%)

- TAN Levels: 2056 mg/L
- Biogas Production: 703 L biogas/kg VS.day
- Enhancement to Control/Blank: 351%

Biogas Production

SSAS-1 > PHAS-2

Biogas Variation: 3%
Results: Semi-continuous CSTR Biogas Production

Side-stream Ammonia Stripping (SSAS)

Anaerobic Digester

RNG

Ammonia stripping column

SSAS-2 (RNG at 10%)

TAN Levels

3153 mg/L

Biogas Production

485 L biogas/kg VS.day

Enhancement to Control/Blank

211%

Biogas Production

29%
Results: Semi-continuous CSTR Biogas Production

Side-stream Ammonia Stripping (SSAS)

- Anaerobic Digester
- Air
- Ammonia stripping column

SSAS-3 (Air at 10%)

- TAN Levels: 3227 mg/L
- Biogas Production: 565 L biogas/kg VS.day
- Enhancement to Control/Blank: 262%

Biogas Production enhancement to Control/Blank,
Results: Semi-continuous CSTR Biogas Production

Control Scenario

Hydrolyzer → Anaerobic Digester

Control (no treatment)

<table>
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<tr>
<th>TAN Levels</th>
<th>7943 mg/L</th>
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<tbody>
<tr>
<td>Biogas Production</td>
<td>156 L biogas/kg VS.day</td>
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<td>Result</td>
<td>Inhibited</td>
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</table>
Conclusions

1. Semi-continuous PM mono-digestion is feasible

2. PHAS showed higher flexibility and lower treatment requirements than SSAS, eventually reducing the cost, energy, and space requirements

3. SSAS can be performed with air or RNG, but is less effective than PHAS
Thank You!