KBS studies on greenhouse gases and milk production footprint in pasture-based dairy systems

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C-Lock Inc.
Rapid City, SD
Single AMS-Stall
Greenfeed system
Greenfeed setup

• Two GF units installed in two A3 Lely milking units (2010 & 2011).
• Currently sampling about 60 cows each and from 1 to 4 periods per cow and day.
• Basic routine:
  • Filter & Callibrations every week
    • 1% CO2 + 500 ppm CH4
    • 1500 ppm CO2 + 1500 ppm CH4
  • CO2 Recovery, once per month (3x per unit)
  • System cleaning w/vaccumm every 2 weeks
Year 2: AMS and feeding systems (FS)

- Robot Stocking rate = 35-48 cows/AMS
- DIM (PC = 180; pTMR = 165; TMR = 183 ± 13.2)
- Parity (PC = 2.4; pTMR = 2.4; TMR = 2.2 ± 0.2)

- PC & pTMR: Strip grazing system (1-2 breaks day)
- Pregrazing 2400 kg/ha & postgrazing 1700 kg/ha
- Pellet concentrate in AMS (17% CP, 35% RUP, 2.8 Mcal) at 1 kg per 6 kg milk
Year 2: AMS and feeding systems (FS)

- TMR: Pellet concentrate in AMS at 1 kg per 8 kg milk
- TMR & pTMR: forage-based Mixed ration once a day at 5:00 am (to 5% orts), 2 pushes/day
- Feed intake in TMR ~ 20% AMS & 80% feedyard

<table>
<thead>
<tr>
<th>Season</th>
<th>Confinement</th>
<th>Pasture-based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TMR</td>
<td>pTMR</td>
</tr>
<tr>
<td>Month</td>
<td>D</td>
<td>J</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>As Feed</th>
<th>As DM</th>
<th>NDF</th>
<th>Mcal kg</th>
<th>CP</th>
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</thead>
<tbody>
<tr>
<td>Haylage (35%)</td>
<td>1.0</td>
<td>0.4</td>
<td>0.50</td>
<td>1.0</td>
<td>0.20</td>
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<tr>
<td>Corn Silage (32%)</td>
<td>0.9</td>
<td>0.3</td>
<td>0.55</td>
<td>0.7</td>
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<tr>
<td>Corn grain</td>
<td>0.2</td>
<td>0.2</td>
<td>0.10</td>
<td>0.6</td>
<td>0.09</td>
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<tr>
<td>Protein Premix, RUP</td>
<td>0.1</td>
<td>0.1</td>
<td>0.12</td>
<td>0.3</td>
<td>0.44</td>
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<tr>
<td>Salt</td>
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<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
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<tr>
<td>MinVitPremix</td>
<td>0.0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
<td>0.00</td>
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<tr>
<td><strong>Total/average</strong></td>
<td><strong>2.3</strong></td>
<td><strong>1.0</strong></td>
<td><strong>2.7</strong></td>
<td><strong>0.17</strong></td>
<td></td>
</tr>
</tbody>
</table>
FS & milk production

Predicted milk (y):
\[ y = ae^{-bx} - ae^{-cn} \]

Brody et al. (1924)

\[ \text{Lac}_{305} = 9,880 \text{ kg} \]

\[ \text{Lac}_{305} = 8,496 \text{ kg} \]

\[ \text{Lac}_{305} = 7,636 \text{ kg} \]
FS & milking frequency
Average rate of enteric CH₄ emissions (g CH₄/h) by a herd of Holstein cows managed with robotic milking and three different feeding systems

Blue arrows indicate the time of delivery of fresh TMR feed

CH₄ emissions reflected differences in feeding/grazing patterns

Non dispersive infrared and gas tracer system in robotic milkers
Rate of enteric CH₄ emissions per unit of milk production (g CH₄/kg Milk) in three feeding systems

Emission of CH₄/milk (not corrected by solids) declined with increases in milk production.

Emission of CH₄/milk across feeding/management systems:
- TMR: $15 \text{ g/kg}$
- pTMR: $17 \text{ g/kg}$
- PC: $19 \text{ g/kg}$

Is there a mitigation threshold around 27-30 kg milk/day across feeding/management systems? $P < 0.04; \text{ SE } \pm 1\text{g}$
Diurnal grazing patterns (GPS)

Supplemental feed (60% haylage)
Diurnal milking patterns of dairy cows managed at two stocking rates and supplement levels
Milking/GF interval of dairy cows managed at two socking rates and supplement levels
Grazing patterns/CH4 emissions
Present outlook

• Greenhouse gas (GHG) mitigation potential is currently limited by lack of system-based approaches quantifying the net GWP and footprint in pasture-based dairies.

• Simulation work (DGAS, DairyGHG), suggest:
  – >50% contributions by enteric CH4 emissions (animal level)
  – 20-30% contributions by N2O and CH4 from grazed pastures (pasture level)
  – Variable potential for soil carbon sequestration (soil level)
**General hypothesis**

**Ecosystem risk, adaptation & mitigation**

- **Production (per head and per area)**
  - Per head
  - Per area

- **GWP**
  - Global warming potential (Net ecosystem CO₂ eq.)

- **Biodiversity/ Resilience**
  - Degradation

- **Grazing pressure/stocking rate/input**

- **Max mitigation per area at moderate SR**
- **Max mitigation per area is not necessarily max mitigation per cow**
- **Biodiversity increases resilience and mitigation potential of grazing lands**
Methods

Net GWP and footprint in pasture-based dairy systems

Enteric $CO_2$ and $CH_4$ flux
Automatic estimates using non dispersive infrared sensors in robotic milkers

Static chambers using KBS-LTER protocols for $CO_2$, $CH_4$, $N_2O$

Soil carbon stocks using soil core samples up to 1.5 m deep

Net GWP = $CO_2$-eq$_{animals}$ + $CO_2$-eq$_{pasture}$) − (Δ$c_{soil}$)

C-Footprint = Net GWP / Milk production
Preliminary results

- Two breeds (USH: Holstein vs. NZF: Friesian) and 2 pasture systems (orchardgrass vs ryegrass) in a CRD.
- Animals: 24 USH (552 ± 6 kg BW) and (342 ± 11 kg BW)
- Rotational grazing of ryegrass- or orchardgrass-based pastures for 8 d.
- Enteric CH₄ sampling using non-dispersive infrared sensors and gas tracer (Greenfeed®)

- Enteric CH₄ flux (g/d) was greater ($P < 0.001$) for USH Vs. NZF, but CH₄ flux per unit of metabolic BW was not different ($P = 0.68$) between breeds (average: $3.43 \pm 0.14$ g/kg BW$^{0.75}$)
Milk production & Footprint

- Milk yield was greater ($P < 0.001$) for USH than NZ cows (right).
- Differences in milk yield between breeds explained the diluted ($P < 0.001$) $CH_4$ per unit of milk in USH compared with NZ cows (left).
Pasture GHG Fluxes

- Factorial of 3 patch types (Grazed only, Grazed + Urine, Grazed + Manure) & 2 pasture diversity systems (High vs. Low) in a RCBD
- Repeated measure analysis at 0, 1, 3, 7, 15 & 30 d after grazing

- Daily $\text{N}_2\text{O}$ and $\text{CH}_4$ flux was affected by a day by patch type interaction ($P < 0.0001$),
Ketosis monitoring

Days in milk

Body weight, kg / Activity, count / Rumination, min / CH4, g

Milk, kg / CO2, 100g

- Rumination
- BW
- activity
- CH4
- Milk
- CO2/100

Ketosis monitoring
Ketosis monitoring

Calving: 06/27/12
FS: PC

2849
2nd lac.

Days in milk

Body weight, kg / Activity, count / Rumination, min / CH4, g / Milk, kg / CO2, 100g

Rumination  BW  activity  CH4  Milk  CO2/100
Displaced abomasum monitoring

Body weight, kg / Activity count / Rumination, min / CH4, g

Days in milk

Milk, kg / CO2, 100g
Power of CH4 estimates

Let say:
- CH4 chamber = \( Y_{ch} \) is collected with \( N_{ch} \) animals
- CH4 Greenfeed = \( Y_{GF} \) is collected with \( N_{GF} \)

If the Correlation (\( Y_{ch}; Y_{GF} \)) = \( r(Y_{ch}; Y_{GF}) = 0.8 \)

\[
N_{GF} = \frac{N_{ch}}{r^2}
\]

In our example if \( N_{ch} \) was 10, then \( N_{GF} = \frac{10}{0.64} = 15 \)
If we use more than 15 animals with GF we will have higher power in methane estimates