An international approach to reduce greenhouse gas emissions from sheep

Joanne Conington
& many others..

ICAR session 8, 24 May 2024

Leading the way in Agriculture and Rural Research, Education and Consulting
Strategies to mitigate greenhouse gas emissions from pasture-based sheep: ‘Grass To Gas’

International Project, 10 partners from 7 countries, 2019-2023

** New project 2024-2027 ‘Sustain Sheep’ **
Key Aims

1. Validate predictors of feed intake, feed efficiency and methane emissions
Key Aims

2. Compare indoor vs outdoor feed efficiency and methane emissions
Key Aims

3. Investigate the opportunity to use genetics and genomics to reduce methane (CH$_4$) emissions
   - genetic control – feed efficiency and methane?
   - impact of genetic selection on CH$_4$?
   - genomic diversity of rumen microbial communities?
   - links between phenotypes and host genome?
Key Aims

4. Quantify economic and environmental benefits of more feed-efficient and lower GHG-emitting sheep

Identify / quantify potential trade-offs via modelling approaches

Ensure relevance from farm to international impact scale
Our focus

• Focus on measuring methane emissions, feed efficiency, potential predictors, animal performance
Direct measurement of methane emissions

Norway, Ireland, France, Uruguay, NZ (& UK 2022+)

Computation of methane emissions, oxygen consumption, CO₂ emission /kg LWT /hr
Mini ‘boxes’ (PACs) to measure CH4 from individual sheep
## Traits measured

<table>
<thead>
<tr>
<th>TRAIT</th>
<th>France</th>
<th>UK</th>
<th>Uruguay</th>
<th>Ireland</th>
<th>Norway</th>
<th>NZ</th>
<th>ICLRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed intake (concentrate)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed intake (forage)</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Feed intake (water)</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>GHG emissions</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Body weights – ADG</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Body composition: ultrasound</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Body composition: CT-scanning and MRI</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Body composition: MRI</td>
<td></td>
<td>X</td>
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<tr>
<td>Carcass traits</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Body condition scores</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Rumen volume (CT scan)</td>
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<td>X</td>
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<td>Blood metabolites</td>
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<td>X</td>
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<td>Genetic markers</td>
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<td>X</td>
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<tr>
<td>NIRS on faeces</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Ruminal datasets</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>RumiWatchSystem</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Feed quality</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Note: The table indicates measurement locations for various traits in different countries and the ICLRT.
NZ- selection for divergent CH$_4$

Suzanne Rowe, pers. comm
Differences between High vs low CH₄ lines
NZ provides evidence of how animals differ

<table>
<thead>
<tr>
<th>Trait</th>
<th>High CH₄</th>
<th>Low CH₄</th>
<th>P-value</th>
<th>Diff.¹</th>
<th>Heritability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reticulo-rumen full (g)</td>
<td>5358 ± 82</td>
<td>5052 ± 83</td>
<td>0.01*</td>
<td>6%</td>
<td>0.19 ± 0.07</td>
</tr>
<tr>
<td>Reticulo-rumen empty (g)</td>
<td>988 ± 8</td>
<td>956 ± 8</td>
<td>0.01*</td>
<td>3%</td>
<td>0.16 ± 0.07</td>
</tr>
<tr>
<td>Est. rumen contents (g)</td>
<td>4370 ± 81</td>
<td>4096 ± 82</td>
<td>0.02*</td>
<td>6%</td>
<td>0.20 ± 0.07</td>
</tr>
<tr>
<td>Papillae count (per cm²)</td>
<td>32 ± 1</td>
<td>31 ± 1</td>
<td>0.61</td>
<td>2%</td>
<td>0.09 ± 0.05</td>
</tr>
<tr>
<td>Av. papillae height (mm)</td>
<td>3.69 ± 0.09</td>
<td>3.92 ± 0.09</td>
<td>0.06</td>
<td>-6%</td>
<td>0.25 ± 0.07</td>
</tr>
<tr>
<td>Av. papillae width (mm)</td>
<td>1.94 ± 0.04</td>
<td>1.95 ± 0.04</td>
<td>0.85</td>
<td>0%</td>
<td>0.10 ± 0.06</td>
</tr>
<tr>
<td>Av. papillae surface area</td>
<td>26.6 ± 1.0</td>
<td>28.5 ± 1.1</td>
<td>0.21</td>
<td>-7%</td>
<td>0.22 ± 0.07</td>
</tr>
</tbody>
</table>

1. Differences

Suzanne Rowe, pers. comm
The rumen volume story cont’d..

NZ - 3 generations of selection to reduce methane (Rowe, 2021)

- 20% difference in RR volume
- associated with 11% of methane emissions

Bigger rumen = more methane

CT reticulo-rumen (RR) volume related to CH$_4$ emissions
Using CT images to predict rumen volume

Testing out on Computer-Tomography (CT)* images from UK breeds

*CT is already routinely used in sheep breeding programmes in some countries for near-perfect estimates of body composition (fat, muscle etc)
Feed intake & efficiency

Feed efficiency:
• Protocols and models further developed and shared (Residual Feed Intake; RFI)
• Between and within-breed variation confirmed
• Moderate $h^2$ RFI  France = 0.45, NZ = 0.42, Uruguay 0.37 (0.08)

Residual Feed Intake (RFI)
= actual feed intake - predicted feed intake
(due to growth, metabolism, composition changes etc.)
Feed intake and efficiency

Feed efficiency:
• Differences between forage-based diets (grass / silage of differing quality) (Ireland)
• Positive correlations between indoor concentrate intake, indoor forage intake and RFI (Norway)
• Feed intake at grazing (n-alkane technique) highly correlated with intake measured indoors (Ireland)
Indoor/outdoor trial - UK

- Lambs grazed outdoors (vs indoors)
  - lower weights, growth, fat and muscle levels
  - greater RR volume
- Feed efficiency (RFI) measured indoors
  - Significant sire differences
  - No clear relationship with RR volume
RFI vs rumen volume?

No clear relationship
Results – indoor vs outdoor (UK)

Significant sire effects (all traits)

Lambs from the same sires ranked similarly in each system for LWT, RFI, reticulo-rumen volume

Feed intake behaviour (no. meals, meal duration etc.) explained large % RFI variation
Results – system/diet effects on RR volume

Lambs grazed outdoors post-trial were:

• significantly larger (P<0.001) liveweight-adjusted reticulo-rumen volume (RRvol)
Key results – CH₄

• Ranking of animals same PAC vs respiration chambers high
• Between and within-breed variation confirmed
• $h^2$ CH₄ g/d = 0.32; CH₄/(CH₄+CO₂)=0.29 NZ* n= 1000
  CH₄ g/hr = 0.17 Norway **(n=4500)
  CH₄ g/d = 0.34(0.09) Uruguay *** (n-930)

*Johnson et al 2022
Front. Genet. Aug 22
https://doi.org/10.3389/fgene.2022.911639

** Jakobsen et al WCGALP
https://doi.org/10.3920/978-90-8686-940-4_34

*** Marques et al 2022
Results RFI vs CH$_4$

Less efficient animals (high RFI) emit more CH$_4$ (g/day & g/kg LWT)

\[ r_g \text{ RFI - CH}_4 = 0.43(0.19) \]

\[ r_g \text{ FI - CH}_4 = 0.75 (0.12) \]

*** Marques et al 2022
Results RFI vs CH$_4$ ?

Johnson et al., 2022 Front Genet 13

$\rho_{RFI - CH_4/CO_2} = -0.13(0.03)$

$\rho_{RFI - CH_4} = -0.41 (0.15)$

The Jury is still out!
Microbiome predictor of CH$_4$

Rumen microbial (genomic) profiles

https://doi.org/10.1371/journal.pone.0219882
Results – not always consensus

Ruminal microbiota – France: no clear relationships

NZ

~4K sheep: \( r_g \) 0.64 feed intake

\( r_g \) \( \text{CH}_4 \) (PAC) vs RMC= 0.66(.13) - 0.76(.14)

Bilton et al., 2022
**4th Aim: Cost effectiveness (CE) and abatement potential (AP) of mitigation measures applied to UK sheep systems**

<table>
<thead>
<tr>
<th>Name</th>
<th>Applied to</th>
<th>CE (£/tCO2e)</th>
<th>AP (ktCO2e)</th>
<th>AP as %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio N fixation in grasslands</td>
<td>Managed grass</td>
<td>-1034</td>
<td>250</td>
<td>2.5%</td>
</tr>
<tr>
<td>Optimising pH for grass growth</td>
<td>Managed grass</td>
<td>-31</td>
<td>278</td>
<td>2.8%</td>
</tr>
<tr>
<td>Breeding for improved productivity</td>
<td>All sheep</td>
<td>-10</td>
<td>504</td>
<td>5.0%</td>
</tr>
<tr>
<td>Breeding for lower CH4</td>
<td>All sheep</td>
<td>20</td>
<td>252</td>
<td>2.5%</td>
</tr>
<tr>
<td>Better health planning for sheep</td>
<td>All sheep</td>
<td>38</td>
<td>391</td>
<td>3.9%</td>
</tr>
<tr>
<td>3NOP*</td>
<td>Non-grazing sheep</td>
<td>119</td>
<td>99</td>
<td>1.0%</td>
</tr>
<tr>
<td>3NOP*</td>
<td>All sheep</td>
<td>158</td>
<td>925</td>
<td>9.2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>2699</strong></td>
<td><strong>27%</strong></td>
<td></td>
</tr>
</tbody>
</table>

*3 Nitrooxypropanol=feed additive

Mike Macleod, Grass To Gas Final report December 2023
Conclusions

- Promising tools have been developed to measure traits related to GHG emissions from sheep
- **Will enable genetic/genomic selection** for reduced methane emissions which will have a direct favourable mitigation impact.
- **Improving productivity** and reducing inefficiencies in the production systems has direct favourable impact on methane intensity, however it may increase absolute emissions. But! selecting for low emitting animals has a positive impact on the reduction of total methane emissions.
- **Almost 30% of abatement potential from sheep can be realised through breeding strategies**
- **International collaboration is key**: Avoids duplication of research effort / funding, pools expertise, accelerates industry implementation, global problem requires global solution
Where are we going next?
International (genomic) comparisons

20 papers published

F. Tortereau, et al., Prediction of feed intake and feed efficiency in sheep: different proxies and models tested in different datasets.
Acknowledgements

Thanks for listening

Nicola Lambe
Suzanne Rowe
Elly Navajas
Flavie Tortereau
Fiona McGovern
+++ all G2G partners
Some interesting facts

• 70 kg ewe emits 0.1 – 2.5g CH$_4$, 15 - 123g CO$_2$ per hour

• 70 kg ewe dry matter intake (DMI) / kg live weight =2.26 kg at pasture

• No difference in ewe CH$_4$ output / kg DMI between grass pellets vs haylage (fed indoors)

• Low-genetic merit for maternal ability ewes did not differ in CH$_4$ output between rough pasture & lowground pasture (in contrast to high-performing or lowground breed).
Genetic parameters for residual feed intake, methane emissions, and body composition in New Zealand maternal sheep

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