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SCHOOL OF ENVIRONMENTAL & RURAL SCIENCE

# Impact of gut kinetics on methane production within the sheep

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# *Abstract*

Methane emissions from ruminant livestock is a major source of greenhouse gases, accounting for approximately two-thirds of anthropogenic methane sources. Methane yield from ruminants (MY; g/kg DM intake) is known to be positively correlated with the mean retention time (MRT) of rumen contents, and MRT in the rumen is largely controlled by the contractile forces of the reticulo-rumen and the relaxing of the reticulo-omasal orifice. The discovery of immuno-reactive endocrine and neural cells distributed throughout the epithelia and glands of the digestive tract suggest that the endocrine system may play a key role in regulating digesta MRT and MY in ruminants. The thyroid hormone triiodothyronine ($T_3$), known to influence digesta kinetics, was used to initiate our studies to modify digesta MRT and determine the impact that digesta MRT has on the production of enteric methane and MY.

To investigate the influence digesta kinetics had on ruminant MY, it was necessary to develop a kinetic model capable of accurately estimating the rate of flow of digesta through the digestive tract. An extensive review of existing published mathematical models for ruminant digesta kinetics was conducted and a model developed by Aharoni *et al*. (1999) for the estimation of cattle digesta kinetics was selected and modified to produce a new multicompartmental double-marker digestive tract model for use in sheep.

Significant reductions in digesta MRT (9%) and MY (14%) with no change in dry matter digestibility (DMD) but increased concentration of ruminal VFA and microbial protein output occurred when plasma concentrations of $T_3$ were elevated within the normal physiological range (Free $T_3$: 1 to 6 pg/mL) of the animal using exogenous $T_3$. When plasma $T_3$ concentrations exceeded normal physiological levels, a negative feed-back loop designed to maintain the animal's homeostasis ensured no changes to either digesta MRT or MY resulted. This study found that $T_3$, which is known to influence digesta kinetics, can reduce digesta MRT and MY in sheep but only when plasma concentrations are within physiological limits.

Noting that after administration of exogenous $T_3$, within a physiological range, digesta kinetics was modified and led to a reduction in MY, the effect of inducing a natural elevation in plasma $T_3$ concentrations on sheep digesta MRT and MY was assessed. Exposing sheep to low ambient temperatures naturally increased plasma $T_3$ concentrations, within a physiological range, and a decrease in digesta MRT resulting in reduced MY was observed. Ruminal VFA concentration and microbial protein output also increased with no change in DMD. Wool growth over the experimental period was measured with cold exposure resulting in a 30% increase in length. The results confirmed that elevating $T_3$ within the physiological range does reduce digesta MRT which results in a reduction in MY. Additional to the reduction in MY was an increase in the animal's productivity through increased wool growth and a significant (30%) reduction in the emissions intensity associated with wool production.

With $T_3$ linked to reductions in digesta MRT and resultant decreases in MY, the usefulness of plasma $T_3$ concentration as a predictor of MY in sheep and, therefore, its potential as an indirect genetic selection tool was assessed. Plasma concentrations of both free and total $T_3$ were found to be correlated with MY and, therefore, show potential as possible predictors of MY in sheep. The correlation was small ($r^2$=0.16) but only a small cohort of animals was used and the relationship between $T_3$ and MY was found to be significant ($P<0.01$).

In conclusion, the thyroid hormone $T_3$ does influence digesta kinetics leading to reductions in digesta MRT and, consequentially, reductions in sheep MY. Triiodothyronine also shows potential as an indirect genetic selection tool for MY, with its significant association with MY. Understanding the key physiological factors which control digesta kinetics may provide new opportunities for indirect selection for MRT and MY by this and other regulators of gut motility.

# *Abbreviations*

| | |
|---|---|
| 5-HT | 5-hydroxytryptamine (Serotonin) |
| AOM | Anaerobically oxidised methane |
| BW | Body weight |
| CCK | Cholecystokinin |
| $CH_4$ | Methane |
| Co | Cobalt |
| $CO_2$ | Carbon dioxide |
| $CO_2$-eq | Carbon dioxide equivalent |
| Compartment | A relatively well mixed, homogeneous body of material |
| Cr | Chromium |
| Digesta MRT | Digesta mean retention time |
| DM | Dry matter |
| DMI | Dry matter intake |
| DMD | Dry matter digestibility |
| DPI | Department of Primary Industries NSW |
| EI | Emissions intensity |
| EOP | Endogenous opioid peptide |
| FSD | Fractional standard deviation |
| FDMO | Faecal dry matter output |
| FSG | Functional specific gravity |
| $FT_3$ | Free triiodothyronine |
| GEI | Gross energy intake |
| GH | Growth hormone |
| GHy | Glycosyl hydrolases |
| GHG | Greenhouse gas |
| GIT | Gastrointestinal tract |
| Gt | Gigatonnes |
| $H_2$ | Hydrogen |
| $H_2O_2$ | Hydrogen peroxide |
| $HClO_4$ | Perchloric acid |
| Hindgut MRT | Hindgut or post-ruminal mean retention time |
| ICP-OES | Inductively coupled plasma optical emission spectroscopy |
| LCFA | Long chain fatty acid |
| LME | Linear mixed effect |
| ME | Metabolisable energy |
| MENK8 | Met-enkephalin-$Arg^6$-$Gly^7$-$Leu^8$ |
| MMC | Migrating myoelectric complex |
| MP | Microbial protein |
| MRT | Mean retention time |
| MY | Methane yield |
| N | Nitrogen |
| $N_2O$ | Nitrous oxide |
| $NAD^+$ | Nicotinamide adenine dinucleotide |
| NADH | Nicotinamide adenine dinucleotide – Reduced form |
| NDF | Neutral detergent fibre |
| NEFA | Non-esterified fatty acid |
| NK | Neurokinin |
| $O_2$ | Oxygen |
| P | Phosphorus |
| PA | Protozoal abundance (cells/mL) |
| PEP-PTS | Phosphoenolpyruvate phosphotransferase system |
| PD | Purine derivatives |

| | |
|---|---|
| PRP | Proline-rich proteins |
| PSM | Plant secondary metabolites |
| RFI | Residual feed intake |
| ROF | Rate of flow (digesta kinetics) |
| ROO | Reticulo-omasal orifice |
| RR | Reticulo-rumen |
| $rT_3$ | Reverse triiodothyronine |
| Rumen MRT | Rumen mean retention time |
| SEM | Standard error of the mean |
| SI | Small intestines |
| SRB | Sulphur reducing bacteria |
| SRIF | Somatotropin release inhibiting factor/Somatostatin |
| SSFSD | Sum of squares of the fractional standard deviation |
| $T_3$ | Triiodothyronine |
| $T_4$ | Thyroxine |
| TK | Tachykinin |
| Total MRT | Total mean retention time |
| TRH | Thyroid releasing hormone |
| TSH | Thyroid stimulating hormone |
| TT | Transit time |
| UNE | University of New England |
| VFA | Volatile fatty acid |
| VFI | Voluntary feed intake |
| VIP | Vasoactive intestinal polypeptide |
| v/v | Volume for volume |

# *Publications associated with thesis*

Barnett, M.C., Goopy, J.P., McFarlane, J.R., Godwin, I.R., Nolan, J.V. and Hegarty, R.S. (2010) The effect of triiodothyronine on mean retention time of rumen digesta and methane production in sheep. Proceeding Sheep CRC Conference (Suppl.) p.25

Poster presentation – Influence of the thyroid hormone Triiodothyronine ($T_3$) on digesta mean retention time (MRT) and methane production in sheep, Sheep CRC Conference 2010 (Supplement), CRC for Sheep Industry Innovation, Adelaide, 2010

Barnett, M.C., Goopy, J.P., McFarlane, J.R., Godwin, I.R., Nolan, J.V. and Hegarty, R.S. (2012) Triiodothyronine influences digesta kinetics and methane yield in sheep. Anim. Prod. Sci. **52**(7): 572-577

Goopy, J.P., Donaldson, A., Hegarty, R.S., Vercoe, P.E., Hayes, F.E.M., Barnett, M.C. and Oddy, V.H. (Accepted) Low methane yield sheep exhibit different gut kinetics, British Journal of Nutrition

Abstract – Barnett, M.C., McFarlane, J.R., Godwin, I.R., Nolan, J.V. and Hegarty, R.S. (2013) Low ambient temperature elevates plasma Triiodothyronine concentrations while reducing digesta mean retention time and methane yield in sheep, Greenhouse Gases & Animal Agriculture (GGAA 2013) conference, Dublin, Ireland, 2013

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