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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 ₂ O 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 ₂ O	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

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