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METHANE EMISSION FROM FORAGE-FED SHEEP, A STUDY OF VARIATION BETWEEN ANIMALS

A thesis presented in partial fulfillment of the requirements for the degree
of Doctor of Philosophy in Animal Science in the Institute of Veterinary,
Animal and Biomedical Sciences, College of Sciences, Massey
University, Palmerston North, New Zealand

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2000


DECLARATION

The studies presented in this thesis were completed by the author whilst a postgraduate student in the Institute of Veterinary, Animal and Biomedical Sciences, College of Sciences, Massey University, Palmerston North, New Zealand. This is all my own work and the views presented are mine alone. Any assistance received is acknowledged in the thesis. All references cited are included in the bibliography.


I certify that the substance of the thesis has not been already submitted for any degree and is not being currently submitted for any other degree. I certify that to the best of my knowledge any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.



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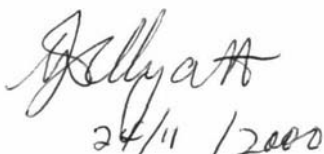


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ABSTRACT

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Rumen methanogenesis represents a loss of between 2 to 15% of the energy intake by the animal, and methane (CH₄) has a role in the global warming phenomenon. Thus, any reduction of ruminant CH₄ emission would have both environmental and nutritional benefits. The development of cost-effective strategies to mitigate ruminant CH₄ without causing a negative impact on animal production, especially for systems based on forages, is a major challenge. Large between-sheep (within a breed) variations in CH₄ emission, under controlled and grazing conditions, have been described in the literature (Chapter 1). This thesis studied the nature and causes of the between-sheep variation in CH₄ emission, with the objective of using it as a tool to reduce CH₄ emission. The sulphur hexafluoride (SF₆) tracer technique was used to measure CH₄ emission throughout this study, therefore three trials were conducted with penned sheep in order to evaluate this technique against the standard respiration chamber (Chapter 2). Poor ventilation in the building and prolonged *in rumen* deployment of the SF₆ permeation tubes were identified as reasons for poor agreement between the techniques in the initial trials. However, when these problems had been overcome, good agreement ($r=0.79$, $p=0.02$) between the techniques was found, with the tracer CH₄ values being 10% lower than the chamber values. The tracer technique was then used to screen grazing sheep for their rates of CH₄ emission, and three groups of sheep (8, 10 and 8 animals), each comprising sheep with low or high CH₄ emissions, were selected, and their CH₄ emissions were monitored during 12, 12 and 5 months, respectively (Chapter 3). This study showed that sheep did not maintain their rankings with respect to CH₄ emission when they were brought from pasture to restricted indoor feeding conditions. However, they did maintain their rankings under generous grazing conditions, although the persistence of rankings weakened with time. A detailed study of rumen digestion (Chapter 4) was carried out with sheep fed indoors on lucerne hay at a restricted level (1.2 maintenance). This study revealed that particulate fractional outflow rate from the rumen (particulate FOR, % h⁻¹) explained a large proportion ($R^2=0.57$) of the between-animal variation in CH₄ emission (%GEI). In addition to the negative relationship to CH₄ emission (%GEI), particulate FOR was negatively correlated with rumen fill (g) ($r=-0.69$, $p=0.03$) and with digestibility of cellulose ($r=-0.65$, $p=0.04$). Based on the latter results, a simple field index for screening grazing sheep for rumen particulate FOR or rumen volume, based on changes in liveweight, was tested (Experiment 1, Chapter 5). LW change during short-term grazing, following overnight fasting, was strongly correlated with maximum

rumen fill (determined at the end of evening grazing). This index was used to screen sheep and to select 10 sheep with 'small' rumen volumes and 10 sheep with 'large' rumen volumes. However, this index was not repeatable in subsequent measurements (Experiment 2, Chapter 5). In a later study (Chapter 6), sheep (6 animals) and alpaca (6 animals), two animal species with known differences in forestomach particulate FOR (lower in alpaca), were successively fed *ad libitum* on three different forages: (1) indoors on chaffed lucerne hay, (2) grazed on ryegrass/white clover pasture (RG/WC), and (3) grazed on *Lotus corniculatus* pasture (Lotus). In general, the quality of diets selected by the sheep, their voluntary feed intakes (per kg metabolic liveweight) and their CH₄ emissions (g d⁻¹) were higher than those of alpaca, but their CH₄ emissions per unit of intake (%GEI) were lower than those of alpaca. On lucerne hay, the digestibility of cell walls was higher and the urinary energy loss lower in alpaca than in sheep. The sheep produced much less CH₄ (%GEI) while grazing on Lotus than on the other feeds, whereas alpaca grazing Lotus showed low values for apparent digestion of cell walls.

In conclusion, this thesis showed that particulate FOR, an animal-related factor, was a major contributor to the between-sheep variation in CH₄ emission (%GEI) and particulate FOR was also suggested to be the underlying mechanism by which alpaca and sheep differed in their rates of CH₄ emission (%GEI). Sheep ranked initially low or high for CH₄ emission rates (%GEI) persisted in their rankings only under generous grazing conditions and this persistence weakened with time. Changes in diet selection or particulate FOR in response to the seasonal changes in pasture quality and composition may have been the reasons for the weakened persistence in CH₄ emission. Future developments in techniques which can measure between-sheep differences in particulate FOR or rumen volume with large numbers of animals under grazing will be useful in the assessment of the benefits of these animal factors for CH₄ mitigation. The depressing effect of *Lotus corniculatus* on CH₄ emissions by sheep shown in this study represents another benefit of condensed tannin-containing temperate legumes for sustainable pastoral production systems.

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LIST OF ABBREVIATIONS

A/P	acetate/propionate
ADF	acid detergent fibre
ADFI	acid detergent fibre intake
ADL	acid detergent lignin
AMRT	apparent mean retention time, h
ATP	adenosine triphosphate
C ₂ H ₆	ethane
CFC	chlorofluorocarbons
CH ₄	methane
CO ₂	carbon dioxide
CP	crude protein
Cr-EDTA	chromium ethylenediaminetetra acetic acid
CT	condensed tannins
d	day
DE	digestible energy
DEI	digestible energy intake
DM	dry matter
DMD	dry matter digestibility
DMI	dry matter intake
DNDFI	digestible neutral detergent fibre intake
DOMR	digestible OM fermented in the rumen
ED	apparent digestibility of energy
F/G	overnight fasting and subsequent grazing
F:C	forage:concentrate
FOR	fractional outflow rate, %/h
g	gram
GC	gas chromatograph
GEI	gross energy intake
Gg	gigagram, 10 ⁹ g
GWP	global warming potential
H ₂	hydrogen
I	infusion rate
IR	intake rate
IRGraz	intake rate during grazing

kg	kilogram
kg ^{0.75}	metabolic liveweight, LW ^{0.75}
Lotus	<i>Lotus corniculatus</i> pasture
LW	liveweight
LWG	liveweight gain
M/D	metabolisability of diet (MJ/kg DM)
MaxFill	maximum rumen fill
ME	metabolisable energy
MEI	metabolisable energy intake
MJ	mega Joule
ml	milliliter
MRT	mean retention time, h
N	nitrogen
n	number of observations
N ₂ O	nitrous oxide
NDF	neutral detergent fibre
NDFI	neutral detergent fibre intake
NH ₃	ammonia
NIR	near-infrared reflectance
O	oxygen
O ₃	ozone
OM	organic matter
OMD	organic matter digestibility
OMI	organic matter intake
PD	purine derivatives
ppbv	parts per billion by volume
pptv	parts per trillion by volume
PR	permeation rate
Q	quantity
RCRFast	rumen clearance rate during fasting
RG/WC	perennial ryegrass/white clover pasture
S	sheep subgroups
SAC	South American camelids
SC	soluble carbohydrates
SF ₆	sulphur hexafluoride

SR	specific radioactivity
STP	standard temperature and pressure
T	trials
Tg	teragram, 10^{12} g
TMR	total mixed ration
VFA	volatile fatty acid
VFI	voluntary feed intake
VR	ventilation rate
Wm^{-2}	watts per square meter
Y_{ATP}	ATP-derived yield of cell mass
$\Delta LwFast$	change in LW during overnight fasting
$\Delta LwGraz$	change in LW during short-term grazing
$[CH_4]$	CH_4 concentration
$[SF_6]$	SF_6 concentration
'calorimetric'	CH_4 measured in respiration chambers
'tracer'	CH_4 measured by SF_6 tracer technique