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METHANE EMISSIONS FROM RUMINANTS FED WHITE CLOVER AND PERENNIAL RYEGRASS FORAGES

A thesis presented in partial fulfilment of the requirements for the degree of

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ABSTRACT

Ruminant enteric methane (CH_4) emissions account for ~35% of New Zealand's total greenhouse gas (GHG) emissions and a commitment has been made for their reduction. Previous research suggested lower CH_4 yields (g/kg dry matter intake; DMI) from sheep fed white clover (*Trifolium repens*) compared to perennial ryegrass (*Lolium perenne*; ryegrass), and the initial focus was to account for that difference. However, measurements undertaken here showed little difference between diets in CH_4 yield. The objective of this thesis was amended to better understand causes of variation in CH_4 emissions from ruminants fed white clover and ryegrass forages.

A database analysis showed greater variation in CH_4 yield from sheep fed ryegrass forages with measured intakes using the SF_6 technique, compared to respiration chambers (23.4 ± 5.70 vs. 23.1 ± 2.90 g/kg DMI). The composition of ryegrass fed to sheep predicted <2% and 20% of the variation in CH_4 yield when derived from SF_6 and respiration chamber techniques, respectively. For cattle, the database of CH_4 yields determined by SF_6 found ryegrass composition accounted for 13% of the variation.

Measurements in respiration chambers of CH_4 yield from sheep in three experiments reported here, had similar values for white clover and ryegrass (22.6 g/kg DMI), despite higher concentrations of fibre and less crude protein in ryegrass. Feed composition predicted less than 19% of variation in CH_4 yield. Measurements of CH_4 emissions from sheep fed white clover or ryegrass at multiples of 0.8 to 2.5 the metabolisable energy requirements for maintenance (ME_m) showed a decline in CH_4 yield of 3.47 g/kg DMI for each multiple of ME_m intake above maintenance. Measurements of rumen function and digesta kinetics, suggested the rate of liquid flow through the gastro-intestinal tract, and molar percentages of propionate were the main drivers of a change in CH_4 yield with intake.

This research has shown minor effects of forage composition on CH_4 yield, and has highlighted the importance of digestive function to account for effects of intake and individual variation on methanogenesis. The benefits of high feed intakes for production will be complemented by a low CH_4 yield and low emissions per unit of production.

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Dedicated in loving memory to my Grandad

Colin James Hammond

31st December 1935 to 5th September 2011

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LIST OF ABBREVIATIONS

A	
(A + B)/P	acetate + butyrate/propionate ratio
ADF	acid detergent fibre
$AgNO_3$	silver nitrate
A:P	acetate to propionate ratio
ATP	adenosine triphosphate
ADP	adenosine diphosphate
B	
bp	base pair
C	
CH_4	methane
CH_4-E	methane energy
CH_4-E/GEI	methane energy relative to gross energy intake
cm	centimetres
Co	cobalt
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalents (weight basis)
CP	crude protein
Cr	chromium
CT	condensed tannins
CV	coefficient of variation
D	
d	day
DDM	digestible dry matter
DDMI	digestible dry matter intake
DGF	dry gas flow
DGGE	denaturing gradient gel electrophoresis
DM	dry matter
DMI	dry matter intake
DNDF	digestible neutral detergent fibre
DNDFI	digestible neutral detergent fibre intake
DOM	digestible organic matter
DOMI	digestible organic matter intake
E	
EDTA	ethylenediamine tetraacetic acid
Ei	emissions intensity
Eq.	equation
F	
FAD^+	flavin adenosine dinucleotide oxidised
FADH	flavin adenosine dinucleotide reduced

Fe^{3+}	iron
FOR	fractional outflow rate
G	
g	gram
GC	gas chromatography
GE	gross energy
GEI	gross energy intake
GHG(s)	greenhouse gas(es)
GIT	gastro-intestinal tract
GWP(s)	global warming potential(s)
H	
h	hour
H_2	hydrogen gas
H_2S	hydrogen sulphide
H^+	hydrogen ion
HCl	hydrochloric acid
HFC(s)	hydrofluorocarbon(s)
HP	hewlet packard
HWSC	hot water soluble carbohydrates
I	
ICP-OES	inductively coupled plasma optical emissions spectrometry
K	
kg	kilogram
KJ	kilojoule
L	
L	litre
LCA	life cycle analysis
LCFA	long chain fatty acids
ln	natural logarithm
LW	live weight
M	
M	moles
m	metres
ME	metabolisable energy
MEI	metabolisable energy intake
ME_m	metabolisable energy requirements for maintenance
MF	methanofuran
mg	milligram
min	minute
MJ	megajoule
ml	millilitre
mM	millimole
mm	millimetre

MRT	mean retention time
MW	molecular weight

N

N	nitrogen
no.	number
n	nano
Na	sodium
NAD^+	nicotinamide adenosine dinucleotide oxidised
NADH	nicotinamide adenosine dinucleotide reduced
$NADP^+$	nicotinamide adenosine dinucleotide phosphate oxidised
NADPH	nicotinamide adenosine dinucleotide phosphate reduced
NDF	neutral detergent fibre
NDFI	neutral detergent fibre intake
NFC(s)	non-fibre carbohydrate(s)
NH_2	amino group
NH_3	ammonia
NIRS	near infrared reflectance spectroscopy
NO_2^-	nitrite
NO_3^-	nitrate
N_2O	nitrous oxide

O

OM	organic matter
OMI	organic matter intake

P

Pa	Pascal
PCR	polymerase chain reaction
PEG	polyethylene glycol
PFC(s)	perfluorocarbon(s)
ppm	parts per million
PPS	protein precipitate solution
P-value	probability-value

R

R	correlation coefficient
R^2	coefficient of determination
REML	Restricted Maximum Likelihood
RFC	readily fermentable carbohydrates
RFC:NDF	readily fermentable carbohydrates to neutral detergent fibre ratio
RFI	residual feed intake
RG	ryegrass

S

SD	standard deviation
SED	standard error of the difference of the mean
SF_6	sulphur hexafluoride
STP	standard temperature and pressure

SOP(s)	standard operating procedure(s)
SO_4^{2-}	sulphate
SSS	soluble sugars and starch
U	
UNFCCC	United Nations Framework Convention on Climate Change
V	
V	volts
VFA(s)	volatile fatty acid(s)
VFI(s)	voluntary feed intake(s)
vs.	versus
W	
WC	white clover
°C	degrees Celsius
ΔG	free energy change
µ	micro
%	percentage
~P	high energy phosphate bond