



MITIGATION OF GREENHOUSE GAS EMISSIONS IN LIVESTOCK PRODUCTION

A review of technical
options for non-CO₂ emissions



Contents

Editors' preface	vii
Abstract	ix
Abbreviations and acronyms	xiii
Introduction	1
Livestock global non-CO ₂ greenhouse gas emissions	1
Scope and approach	5
Approach	6
Mitigation practices	9
Enteric fermentation	10
Introduction to stoichiometry of rumen carbohydrate fermentation	10
Feed supplements	14
<i>Inhibitors</i>	14
<i>Electron receptors</i>	15
<i>Ionophores</i>	18
<i>Plant bioactive compounds (PBAC)</i>	19
<i>Dietary lipids</i>	25
<i>Exogenous enzymes</i>	32
<i>Direct-fed microbials</i>	33
<i>Defaunation</i>	35
<i>Manipulation of rumen archaea and bacteria</i>	36
Feeds and feeding management	37
<i>Effect of feed intake</i>	37
<i>Concentrate inclusion</i>	40
<i>Forage quality and management</i>	47
<i>Feed processing</i>	54
<i>Mixed rations and feeding frequency</i>	56
<i>Precision feeding and feed analyses</i>	58
<i>Mitigation options for production systems based on low-quality feeds</i>	60
Manure and manure management	64
Diet manipulation and nutrient balance	68
<i>Dietary management and N₂O emissions from manure</i>	68
<i>Dietary protein content</i>	70
<i>Dietary tannins (ruminants only)</i>	72
<i>Dietary manipulation</i>	79
Biofiltration	82
Manure storage and separation	84

Manure storage covers	85
Manure acidification	86
Composting	88
Anaerobic digestion	89
Manure application	93
Urease and nitrification inhibitors	96
Control of manure greenhouse gas emissions through grazing practices	98
Cover cropping	99
Other manure treatments	100
Animal husbandry	100
Enhancing animal productivity	100
<i>Recombinant bovine somatotropin (rbST)</i>	104
<i>Animal genetics</i>	105
<i>Animal health and mortality</i>	109
Animal fertility	111
Species summaries by management system	117
Interactions among mitigation practices	121
Interactions in the rumen	121
Protozoal-methanogen relationships	121
N retention and CH ₄ emissions	124
Interactions among feed additives, ration, enteric CH ₄ and animal productivity	125
Interactions among feeding practices, manure storage and land application	128
Interactions among nutrition, animal health and productivity	132
APPENDIX 1	
Enteric methane prediction equations	135
APPENDIX 2	
Mitigation options summary table	137
Bibliography	149

FIGURES

1	Supply chain contribution to carbon footprint of 'generic' milk in the U.S. (2007 data)	3
2	Total emissions from the global livestock sector, by main animal species and commodities	4
3	Carbohydrate metabolism in the rumen	13
4	Relationship between dietary DM intake and enteric CH ₄ production	40
5	Effect of feed intake and proportion of concentrate in the diet on Y _m factor (CH ₄ energy, % of GE intake)	43
6	Flow of organic carbon through the livestock production system including opportunities to mitigate methane emissions from livestock manure	67
7	Flow of nitrogen and organic carbon through the livestock production system including opportunities to mitigate nitrous oxide emissions from livestock manure	69
8	Proportion of ammonia-N emitted from manure originating from faecal or urinary N	73
9	Relationship of metabolizable protein (MP) balance (NRC, 2001) and under-prediction of milk yield in dairy cows (from Lee <i>et al.</i> , 2012b)	77
10	World cereal grain production and population growth	103

TABLES

1	Feed additives and feeding strategies offering non-CO ₂ greenhouse gas mitigation opportunities	138
2	Manure handling strategies offering non-CO ₂ greenhouse gas mitigation opportunities	140
3	Animal management strategies offering non-CO ₂ greenhouse gas emission intensity reduction	143
4	Reproductive management strategies offering non-CO ₂ greenhouse gas mitigation opportunities	144
5	Examples of interactions among non-CO ₂ greenhouse gas mitigation practices	146