Scientific challenges facing agricultural greenhouse gas mitigation in livestock systems

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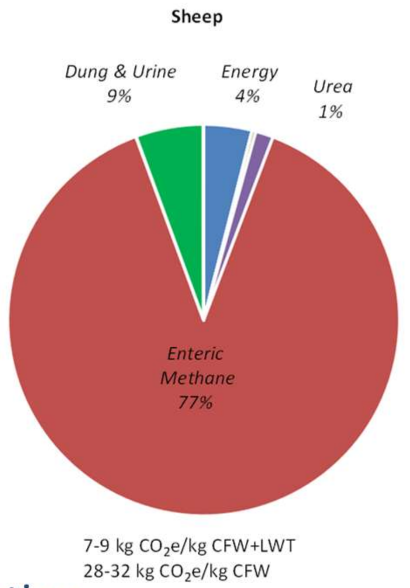
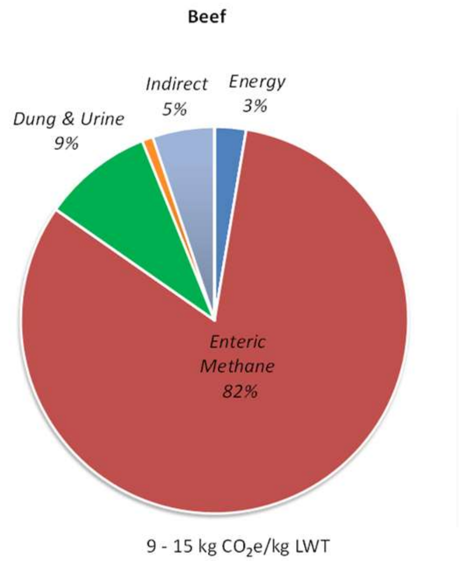
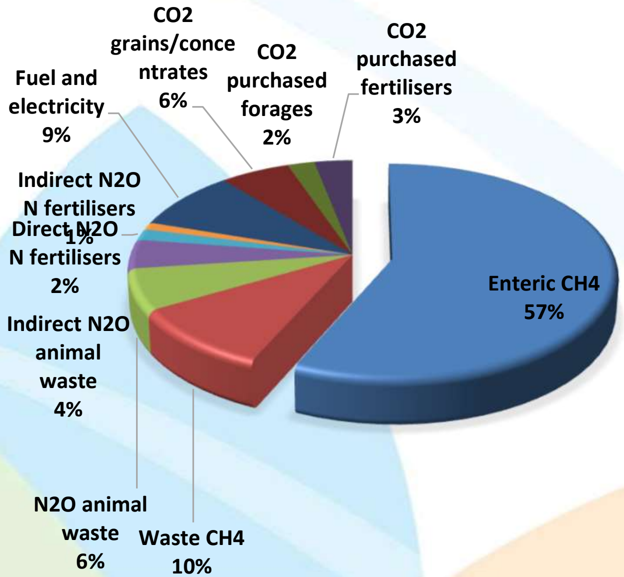
Agricultural emissions

- Methane
  - Ruminants, waste management
    - GWP_{20} = 84
- Nitrous Oxide
  - Fertilizer, excreta, waste, legumes etc.
    - GWP_{100} = 265
- Carbon Dioxide
  - Energy, lime, urea application and fertilizer production
- Sequestration
  - Soil and trees



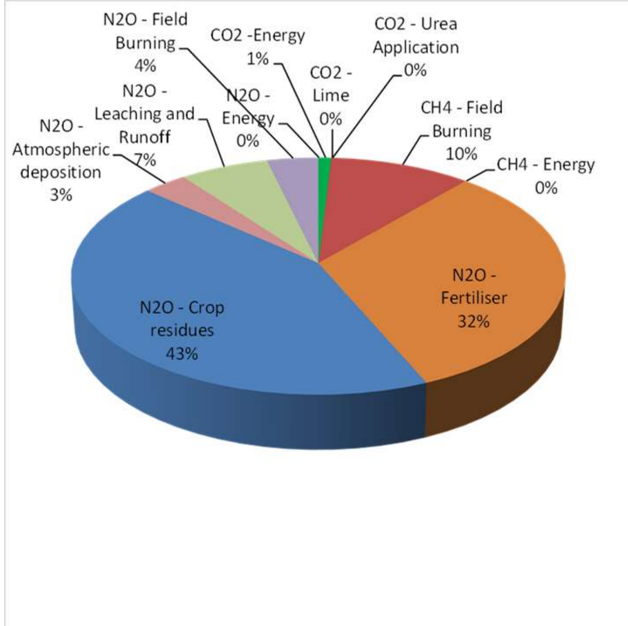


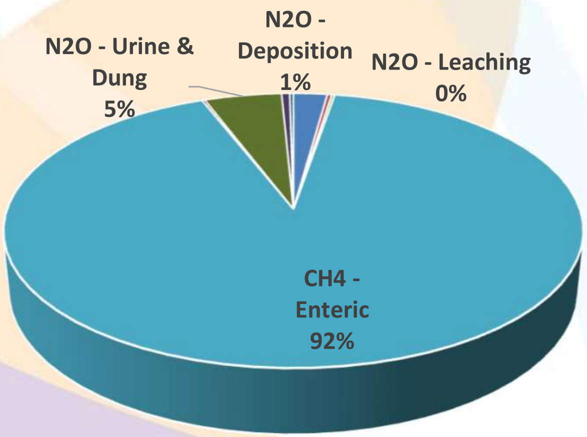
Typical Farm GHG profiles



Dairy
8 – 21 t CO_2 e/t MS

Grains / pulses
0.04 t/CO_2e/t grain





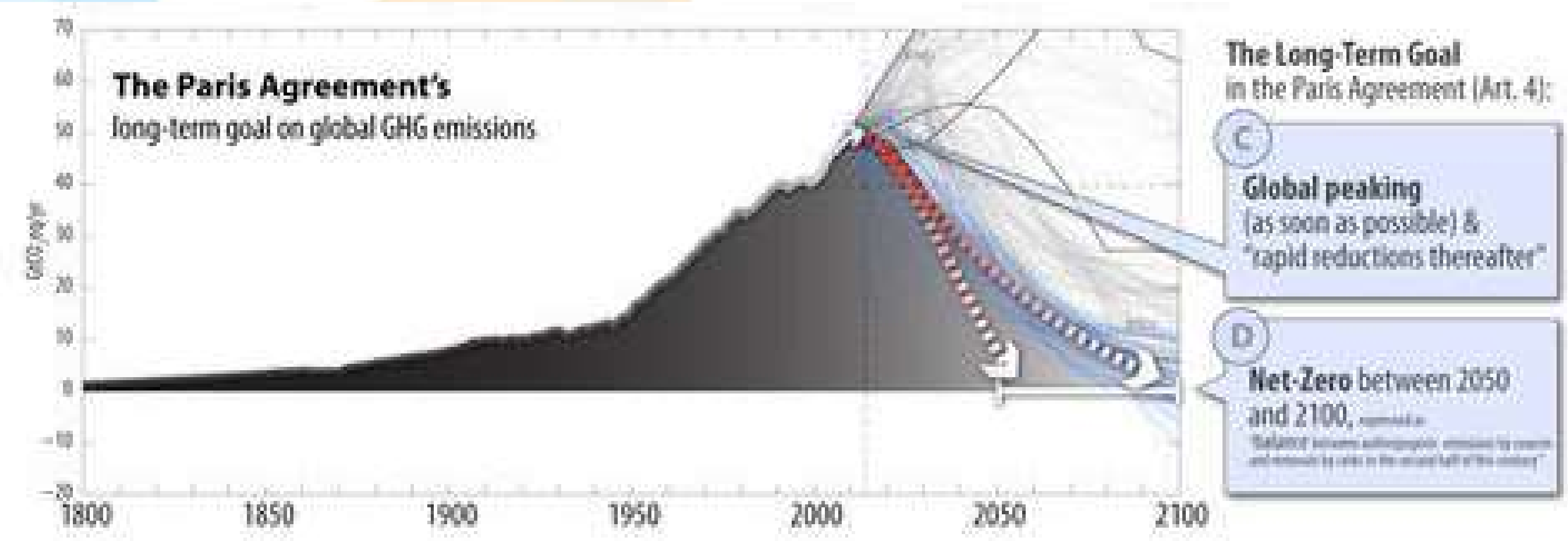
Rangeland Beef
14 t CO_2e/t LWT

Christie *et al.* 2016

The Paris Agreement and
Drivers for Carbon Neutral Agriculture

Drivers of Carbon Neutrality
COP21 Paris Agreement

- Net zero emissions from 2050
  - Any remaining GHG emissions need to be offset
  - Business and governments are aiming to comply



Drivers of Carbon Neutrality
Supply chain responses to Paris Agreement

- Unilever
  - 50% by 2030, compared to baseline of 2010
- Fonterra
  - Climate-neutral growth to 2030
- Mondelez
  - Reduce absolute GHG from manufacturing 15%
  - 100% renewable energy
- Nestle
  - Zero environmental impact in our operations
- Heineken
  - Carbon neutral barley-malt supply chain
- Mars
  - 27% by 2025 and 67% by 2050 (from 2015 levels)
- Kellogg Company
  - 65% reduction by 2050
  - 100% renewable energy
- Pfizer
  - 60 to 80% by 2050
- Wilmar international
  - ~90% less GHG from 2013 to 2020
  - 100% renewable energy
- Olam
  - 50% by 2030 and positive by 2050

- **Of the 100 largest economies 69 are companies and 31 are countries**

Drivers of Carbon Neutrality
Livestock Industry Responses

- Meat and Livestock Australia
  - Carbon neutral red meat by 2030 (CN30)
- Mato Grosso do Sul, Brazil
  - MS carbon neutral initiative
    - *43% by 2030, zero by 2050*
  - Carbon neutral Brazilian Beef
- New Zealand
  - Climate Change Response Amendment Act 2019
    - *30% by 2030, net zero by 2050*
    - Includes agriculture

Australian Beef Sustainability Framework

carbon neutral brazilian beef

Scientific challenges

Key reference

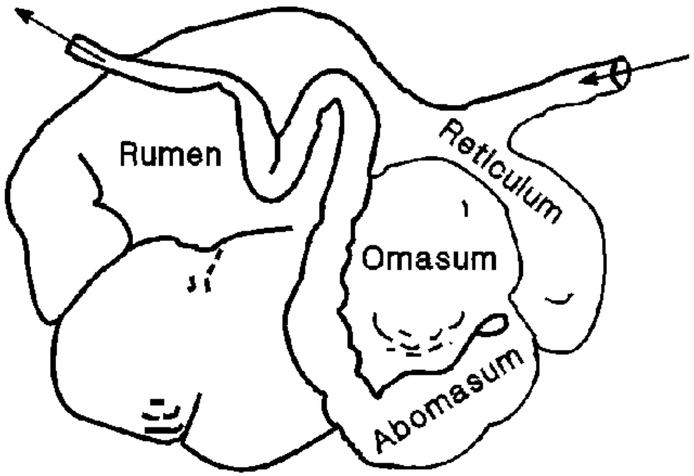
Animal (2020), 14:S1, pp s2–s16
doi:10.1017/S1751731119003100

Review: Fifty years of research on rumen methanogenesis: lessons learned and future challenges for mitigation

K. A. Beauchemin[1†], E. M. Ungerfeld[2], R. J. Eckard[3] and M. Wang[4]

Rumen digestion

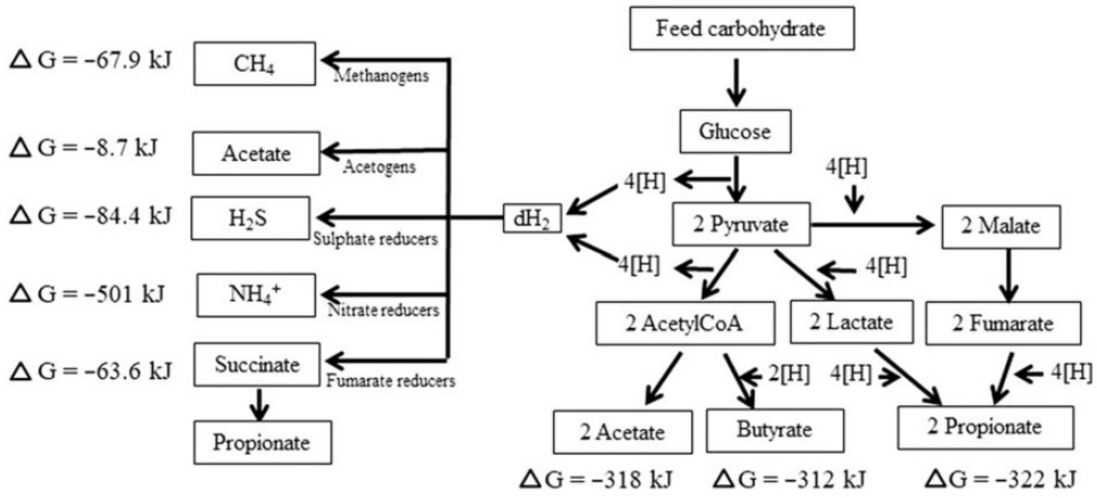
- Ruminants evolved 4 stomachs about 50M years ago
  - We aim to change this in 30 years
  - Adaptation to mitigants is a challenge
- Rumen = Microbial fermentation
  - 40-60% bacteria & protozoa
    - 10^{11} & 10^{6} cells/ml over 200 species
  - 5-10% fungi
    - 10^{6} zoospores/ml
  - 3% Archaea (*methanogens*)
    - 10^{8} cells/ml



Hackmann & Spain (2010)

Methanogenesis

- A form of anaerobic respiration
  - Using the H_2 and CO_2 from VFA formation
    - $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$
- Most energetically efficient process
  - To dispose of metabolic H_2 and CO_2 as CH_4
- Not essential for digestion
  - Block or redirect energy

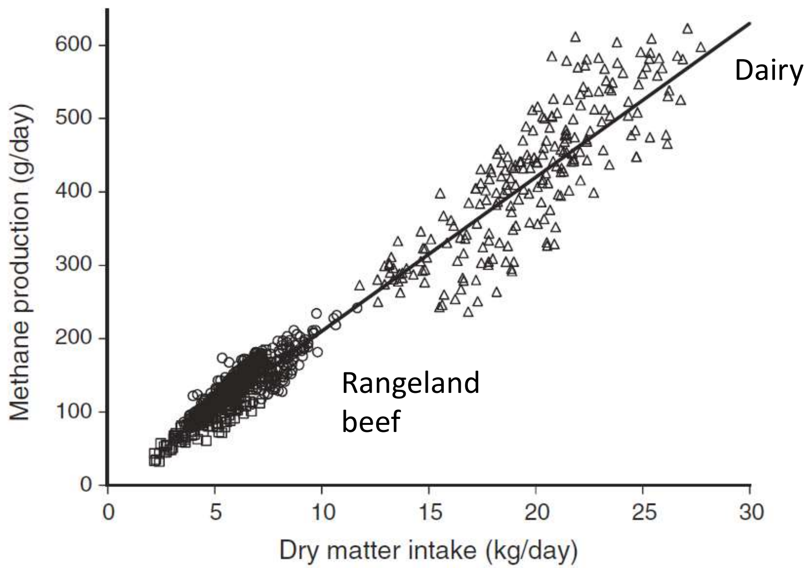


Beauchemin, Ungerfeld, Eckard and Wang (2020)

Factors affecting enteric methane loss

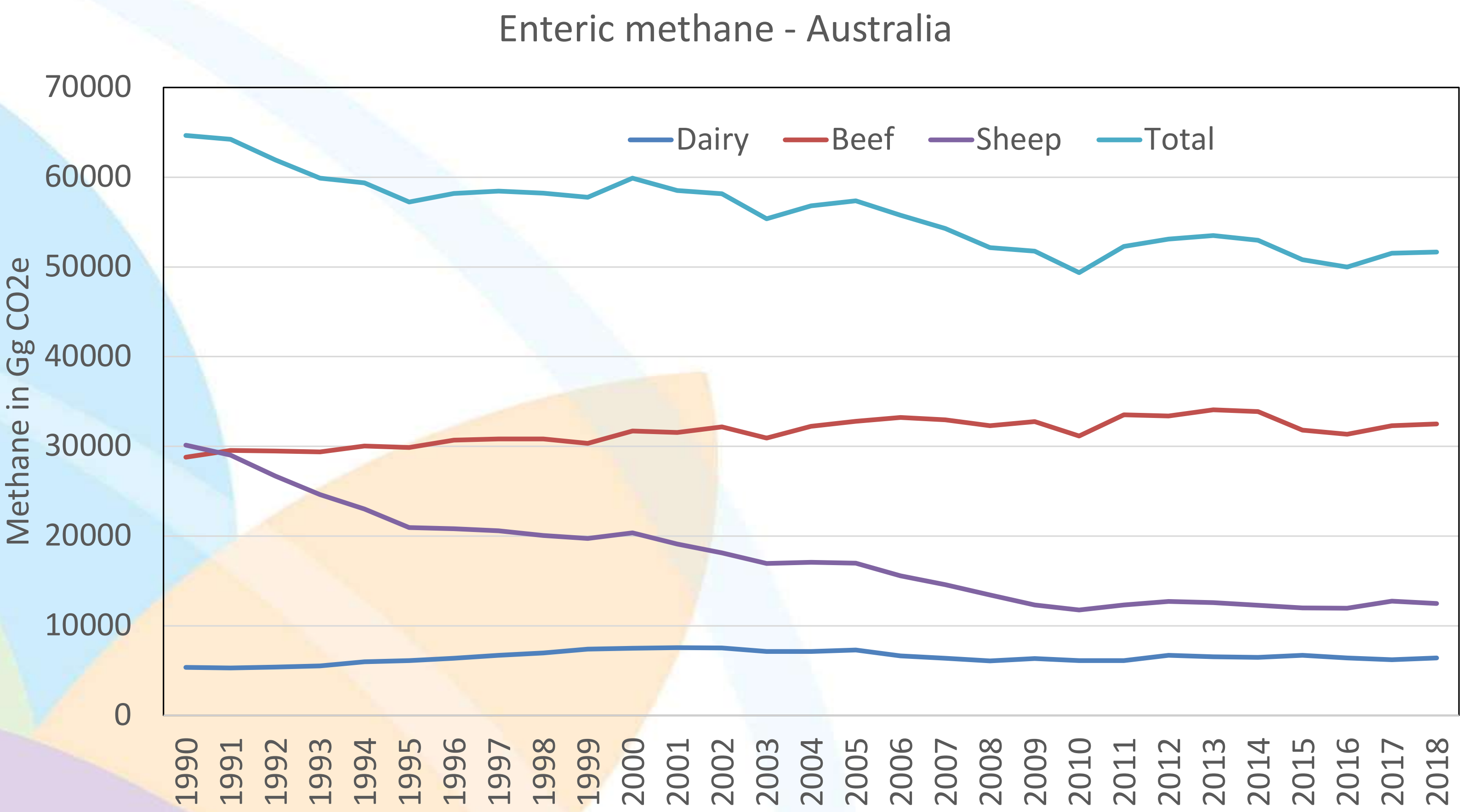
- Rumen passage rate /forage quality
  - More/less time producing methane
  - More propionate
- Rumen pH
  - More acid less CH_4
- Secondary compounds
  - Tannins, saponins, oils
- Direct inhibitors
- Vaccines

Methane (g/day) = 20.7 x kg DMI /day



Charmley *et al.* (2016)

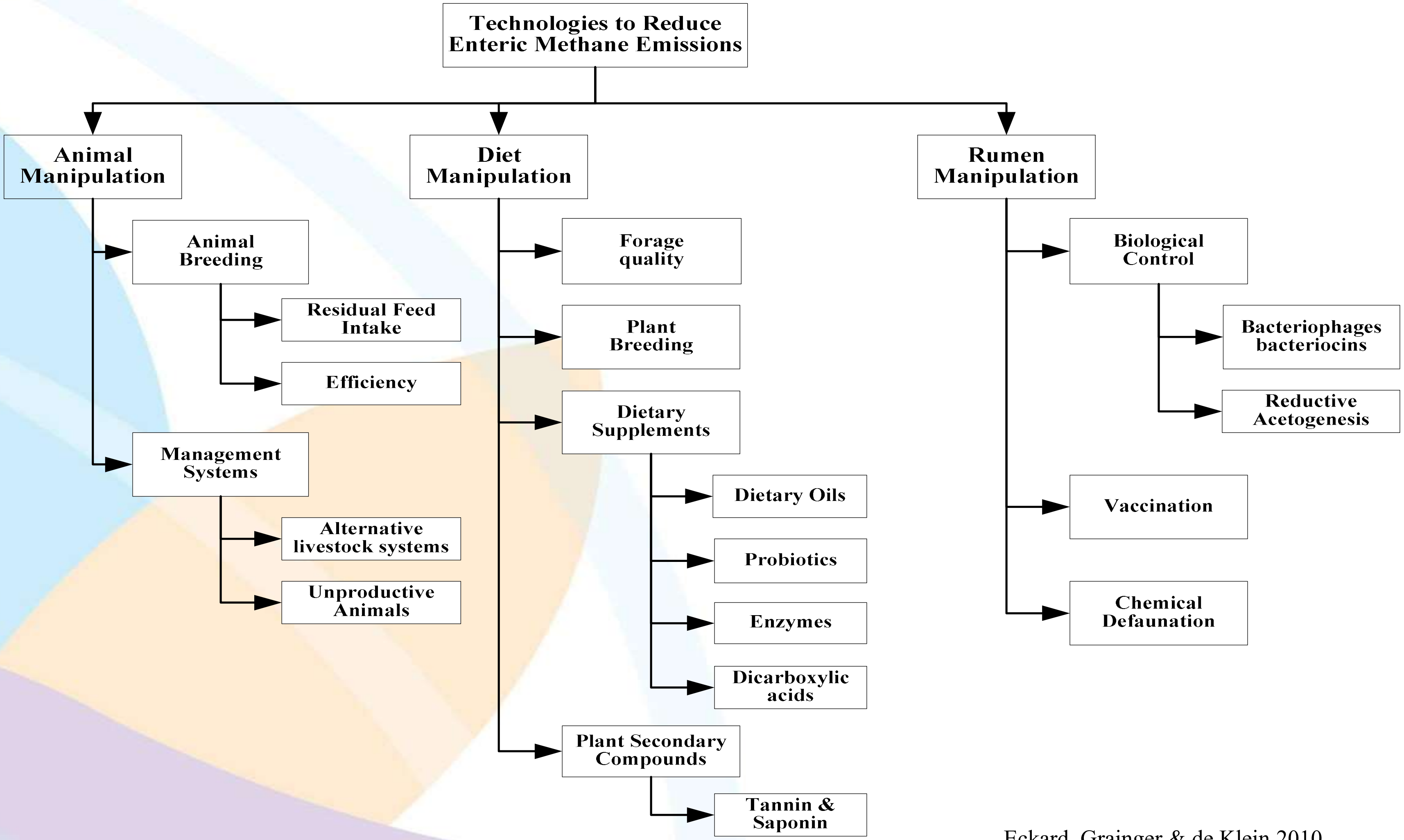
Trends in absolute methane – Australia



AGEIS (2021)

Options for reducing methane in animal production

Methane mitigation options



Eckard, Grainger & de Klein 2010

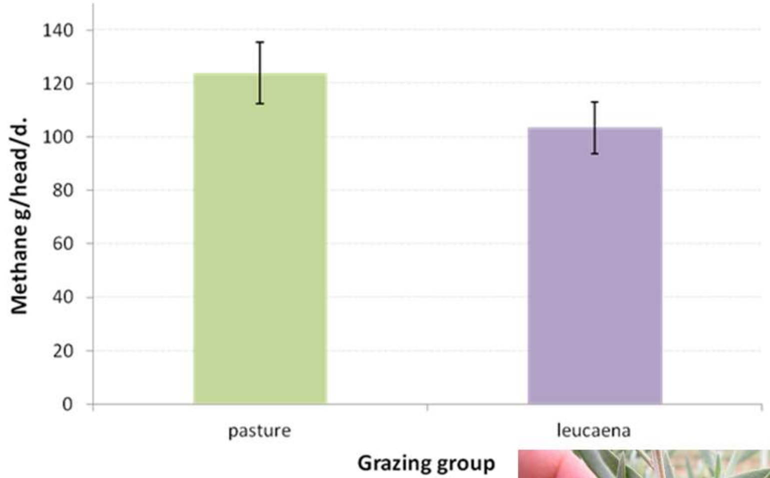
Options for reducing enteric methane
Animal Productivity

- Reducing unproductive animal numbers
    - Earlier finishing, reproduction, fertility, weaning %
    - Improve animal health
    - Larger potential in LMICs
  - Reduces g CH_4/kg product
- Animal Breeding
  - Reduced methanogenesis
    - Low heritability and slow gains (<1% /year)
    - Could be breeding for rumen passage rate?
  - Feed Conversion Efficiency
    - Moderate heritability
    - Reduces g CH_4/kg product

Pickering et al. (2015); Pinares-Patiño et al. (2013); Cabezas-Garcia et al. (2017); J. Lassen, Viking Genetics); Beauchemin, Ungerfeld, Eckard and Wang (2020)

Options for reducing enteric methane
Nutrition

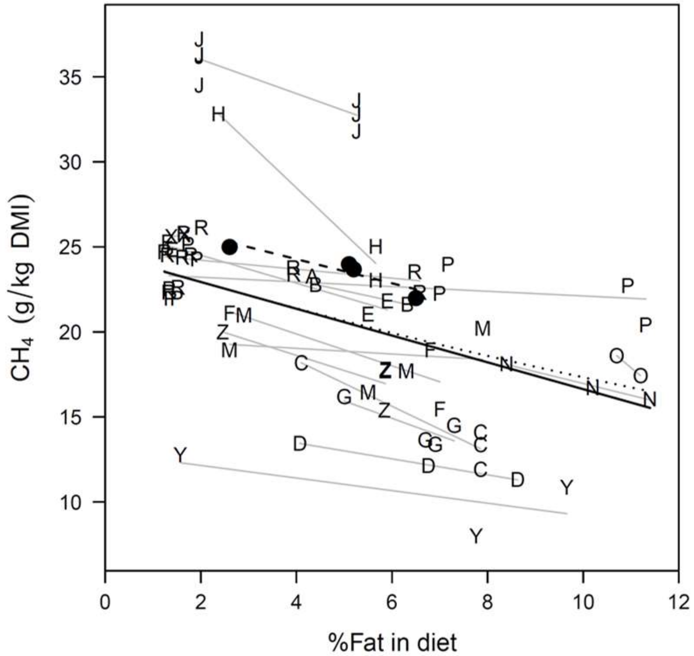
- Forage digestibility
    - e.g. better pastures & grazing management
  - More propionate – less CH_4
- Forage properties
  - Legumes (~10%)
    - Leucaena, Lucerne, Vetch, Lotus
  - Native Shrubs
    - *Eremophila*



Sun et al. (2015); Jonker et al. (2017; 2018); Beauchemin, Ungerfeld, Eckard and Wang (2020); Charmley *et al.* (2015)

Options for reducing enteric methane
Nutrition

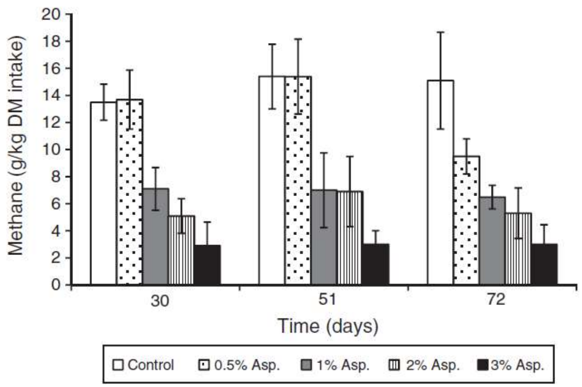
- Oils (~20%)
  - 1% added fat = 3.5% less CH_4
- Tannins (10-15%)
  - Forage legumes
    - Extensive grazing and LMIC
- Tannin + Oil
  - Grape marc (~20%)
    - Oil + tannin

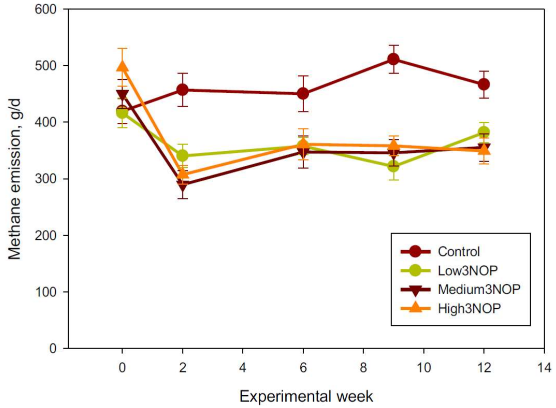


Moate *et al.* (2011)

Options for reducing enteric methane
Rumen

- Methane inhibitors
  - Asparagopsis / Seaweed (>80% or 5.3 g CH_4/kg DMI)
    - Co-enzyme inhibitor
    - *Bromoform & iodine?*
  - 3-nitrooxypropanol (3-NOP) (~70%)
    - Co-enzyme inhibitor
    - EU registration 2021
- Limited in extensive grazing
  - Inhibitor efficacy related to supply
  - Need slow release technology
- Limited in LMICs
  - Cost!

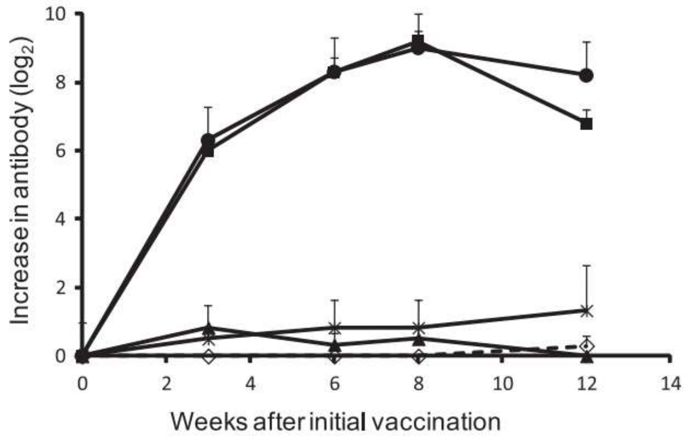




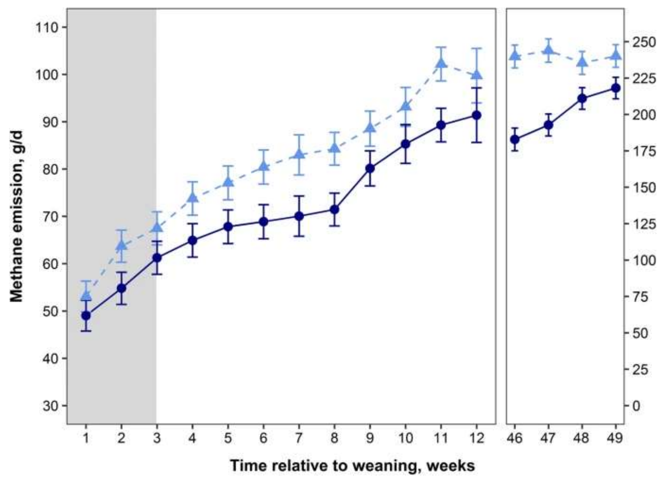
Roque *et al.* 2021: Lean *et al.* 2021; Tomkins *et al.* (2015); Van Nevel and Demeyer (1996); Machado et al. (2014); Li et al. (2018); Eckard and Clark (2018); Li et al. (2018); Hristov *et al.* (2015);

Options for reducing enteric methane
Rumen

- Vaccine (20%?)
  - Antibodies in saliva
  - Suited to more extensive grazing
  - Potential solution for LMICs



- Early life programming
  - Programming the rumen early in the animal's life
  - Early evidence, persistence?
  - Most suited to extensive grazing and LMICs



Wedlock et al. (2013); Yánez-Ruiz et al. (2015); Eckard and Clark (2018); Meale *et al.* (2021)

Challenges facing mitigation in livestock systems

- Research has moved
  - 20% to 80% CH_4 mitigation options
- Current opportunities
  - Animal Management
  - Nutrition
  - Inhibitors
- Challenges
  - Options for extensive grazing and LMICs
- Future opportunity
  - Early life programming

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