Nutritional strategies related to sustainability and efficiency of the U.S. beef industry

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U.S. Beef Industry

- Traditionally segmented
  - Cow-calf (purebred and commercial)
  - Stocker/backgrounding
  - Finishing phases
- Evolving into a total production system
  - Livestock and environmental stewardship
  - Economic sustainability
  - Social responsibility

U.S. Beef Industry

Consumer

↘ Retailer

↘ Packing Industry

↘ Feedlot sector

↘ Backgrounding sector

↘ Commercial cow/calf

↘ Seedstock

U.S. Land: 0.785 billion hectares

- 23.3% is water or federal land
- Non-federal land: 34.7% rangeland, 34.7% forest land, and 30.6% cropland
- Over 4.5 million metric tons of crop residues annually
- 37 kg of byproducts available for livestock for every 100 kg of plants grown for human food

Advantages of Ruminants

- About 35% of the U.S. land surface is rangeland.
- Ruminants can utilize the largest carbohydrate (CHO) source in the world and produce food and other products for man.
- Microbial digestion maintains the carbon cycle. Plants fix CO_2 and release O_2 (85 billions tons of CO_2 released each year from microbial fermentation).

Rumen Ecosystem

- Catabolic processes are collectively thought of as "fermentation".
  - "Fermentation is the consequence of life without air" (Louis Pasteur).
  - VFA are fully reduced, energy dense compounds. Microbes grow and end products are absorbed.
- Anabolic processes are critical:
  - Supply of protein of relatively high biological value, from protein and NPN sources.
  - To meet the B-vitamin requirements of the host.

Advantages of Pregastric Fermentation

- More effective use of fermentation end-products including:
  - Volatile fatty acids, microbial protein, B vitamins
- Ability to detoxify some poisonous compounds
  - Oxalates, cyanide, alkaloids
- Undigested residues (OM) returned to the soil
- In wild animals, it allows animals to “eat and run”

Disadvantages of Pregastric Fermentation

- Inefficiencies in fermentation
  - Energy
    - <u>Loss | Amount (% of total caloric value)</u>

Loss	Amount (% of total caloric value)
Methane	5-8
Heat of fermentation	5-6

    - Relative efficiency is dependent on the diet NDF.
  - Protein
    - Some ammonia resulting from microbial degradation will be absorbed and excreted
    - 20% of the nitrogen in microbes is in the form of nucleic acids
- Ruminants are susceptible to acidosis and ketosis
- Ruminants are susceptible to toxins produced by rumen microbes
  - Nitrates → Nitrites
  - Urea → Ammonia
  - Nonstructural carbohydrates → Lactic acid
  - Tryptophan → 3-methyl indole
  - Isoflavonoid estrogens → Estrogen

Forage use in Beef Production Systems

	Metric Tons
• Forage for Cows/Replacements	640
• Forage for Calf Finishing	18
• Grain for Calf Finishing	140
• Total forage	658
• Total feed	798

- **Beef Production is > 80% forage**

Feed Consumption in Beef Production Systems

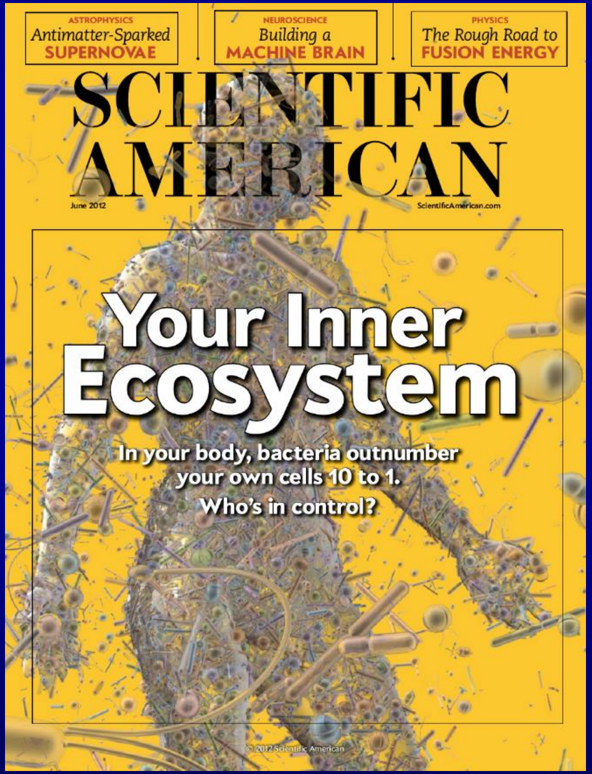
	kg DM/kg CW
• Grazed forage	13.2
• Harvested forage	5.1
• Grain concentrate	2.6
• Other feed	1.5
• Total feed	22.3

- **Beef Production is > 80% forage**

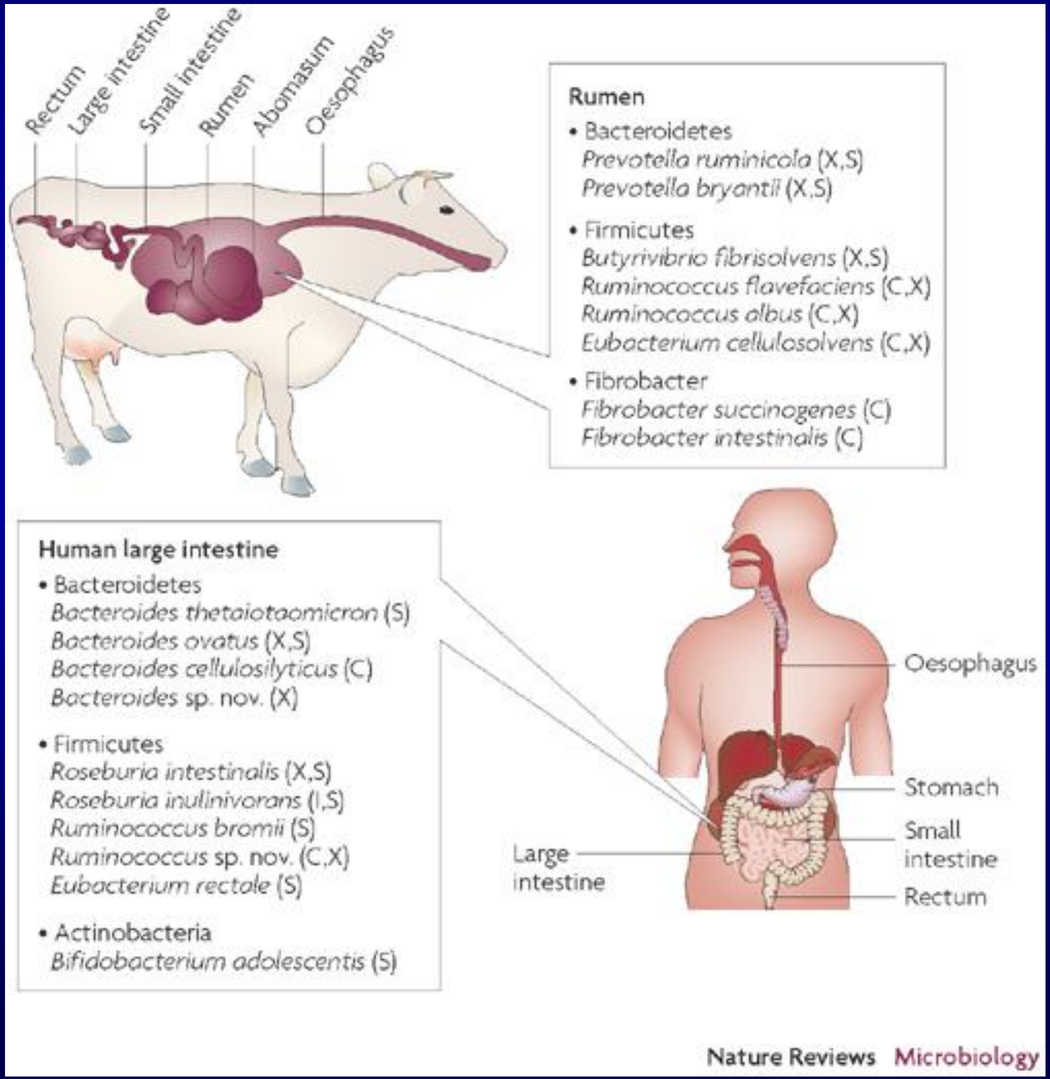
(Rotz et al., 2019)

Humans vs. Ruminants

We’re only 10% human



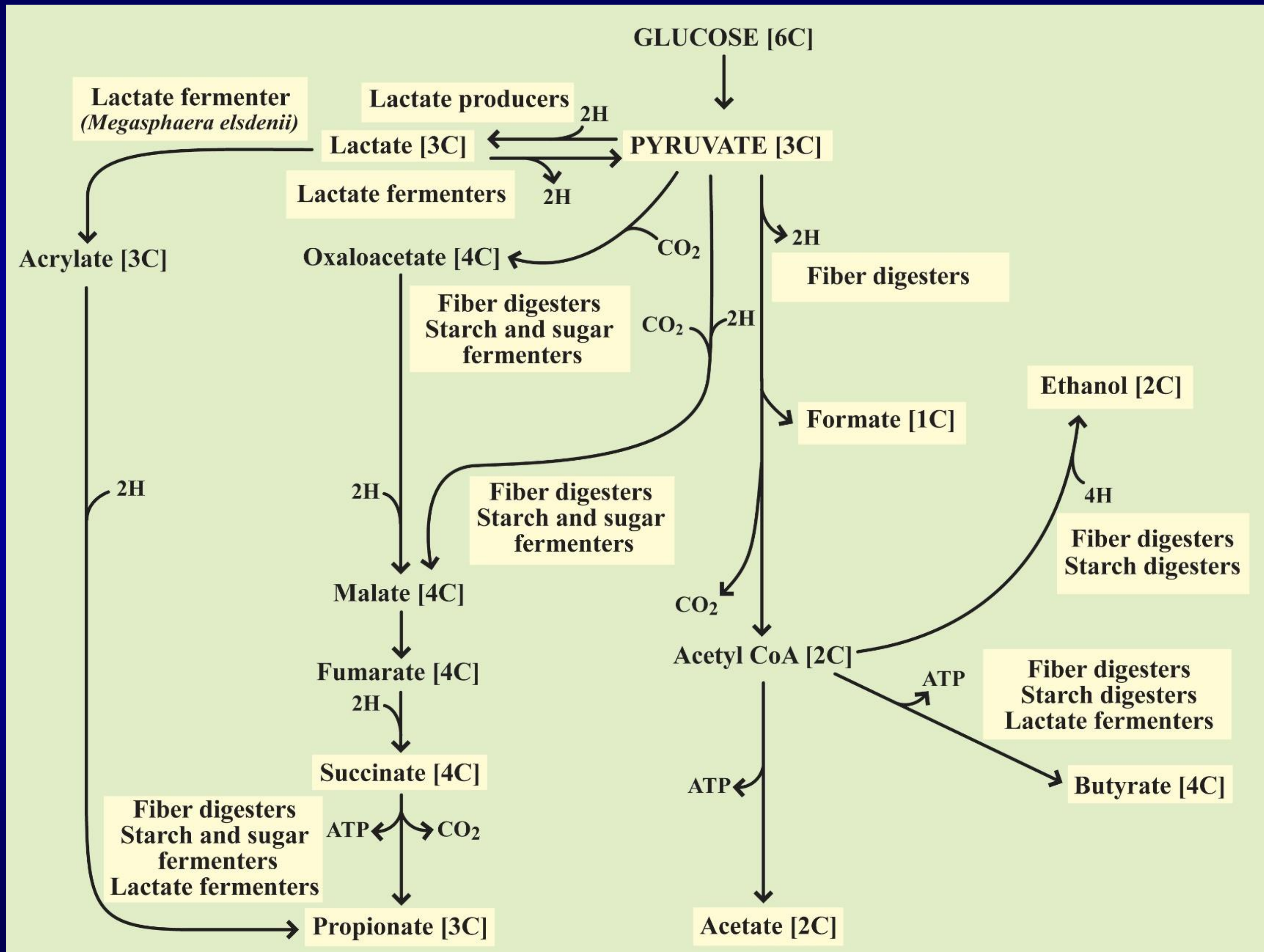
Human microbiota to ruminants – polysaccharide utilization



- 70% of energy from microbial breakdown
- Mutualism
- Dietary polysaccharides that reach the large intestine impact microbial ecology
- **“Diet influences microbial community”**

Nature Reviews Microbiology 6, 121-131 (February 2008) |

Pyruvate Metabolism in the Gut



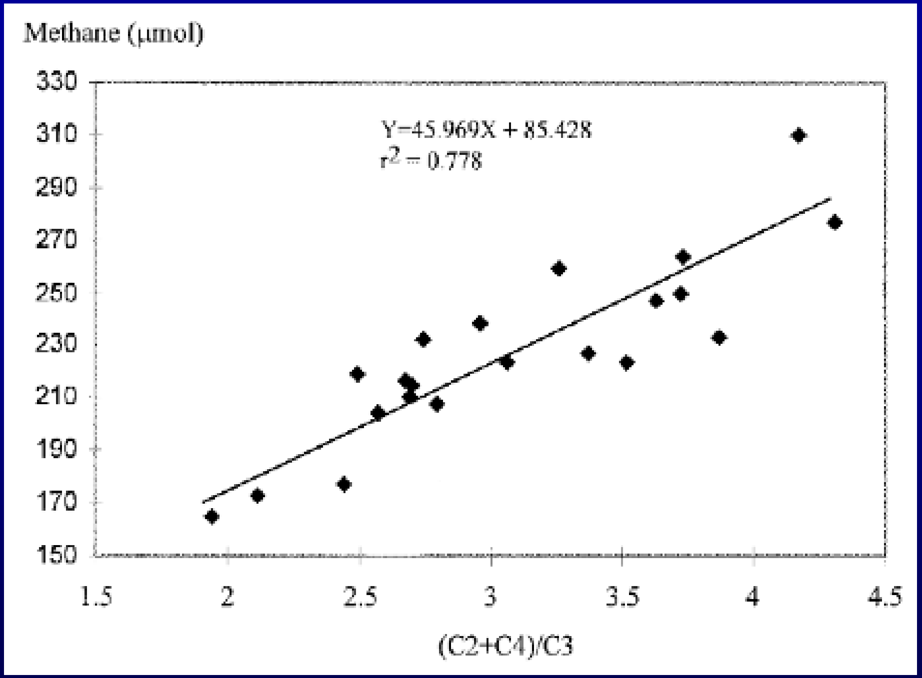
Courtesy of Dr. Nagaraja (Kansas State University)

Key Points

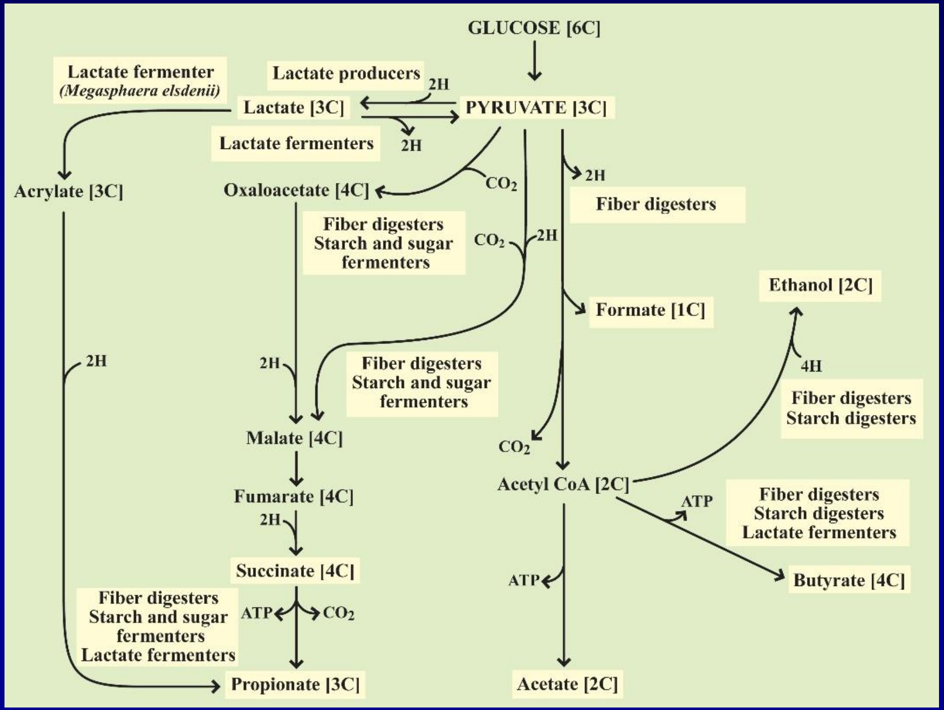
- Polymers are converted to monomers and are phosphorylated

  - Enter different pathways
- Pathways are interconnected and make intermediates that feed back into glycolysis
- Glycolysis is key in microbial metabolism to produce pyruvate
- Pyruvate is used for VFA production
- VFA produced are metabolized by the host for energy
  - Acetate and butyrate – produce H_2
  - Propionate, lactate and ethanol – use H_2

Methane and VFAs

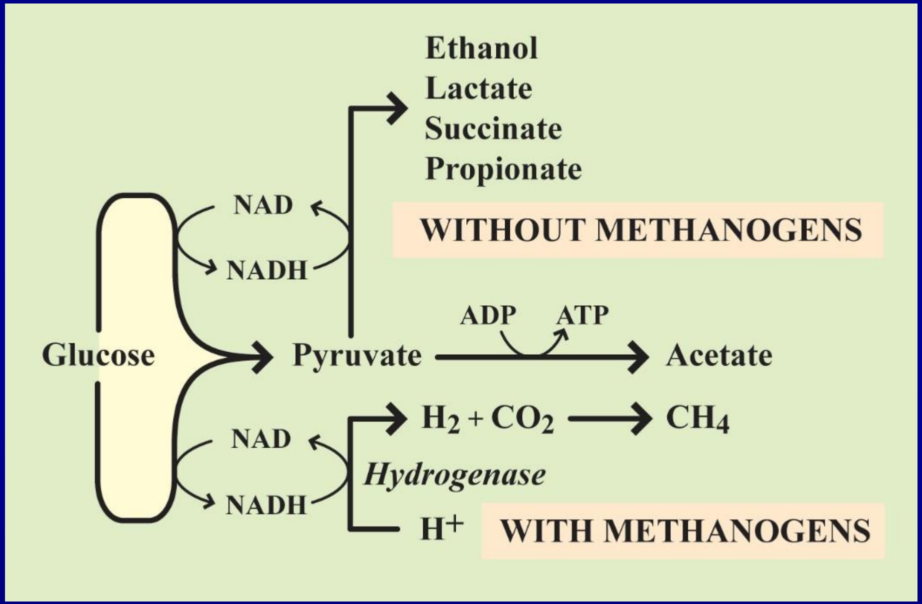


Moss et al. Annales De Zootechnie, 49: 231-253

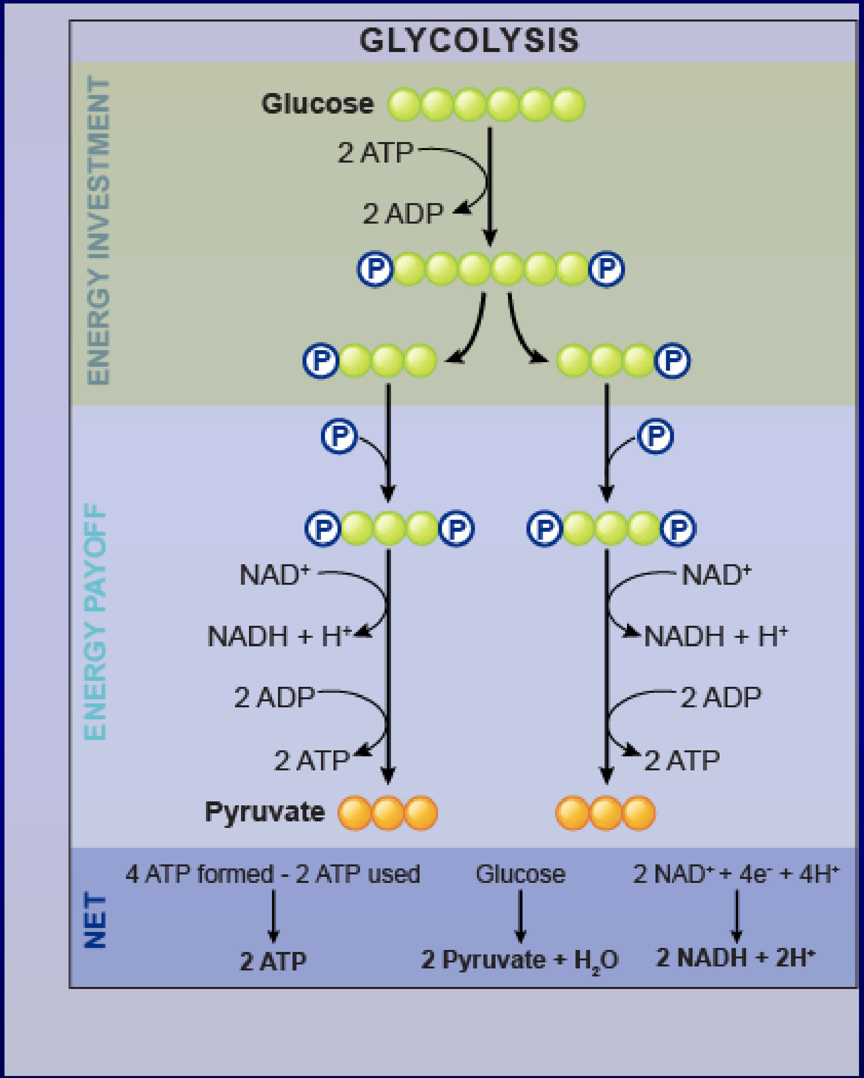


Courtesy of Dr. Nagaraja et al. (Kansas State University)

Inter Species Hydrogen Transfer

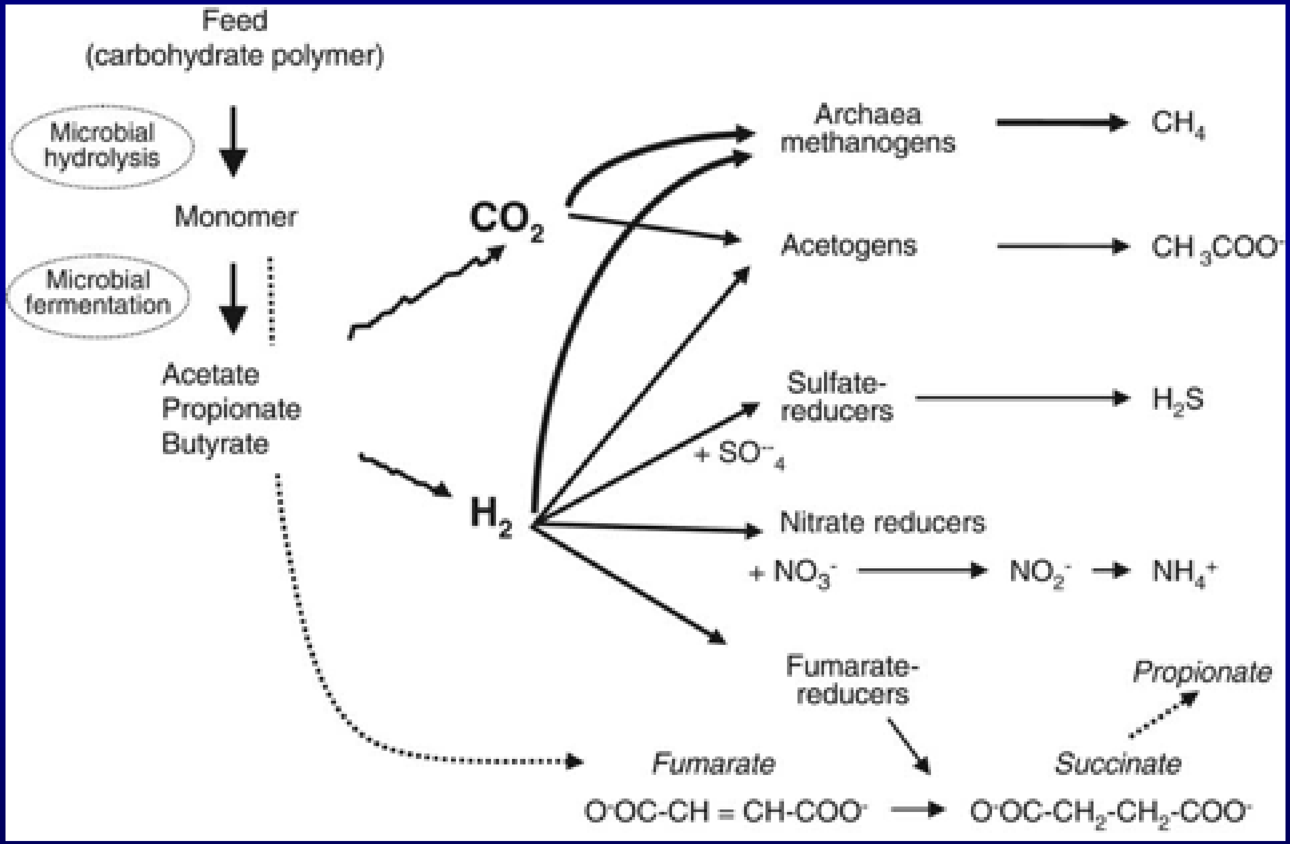


Courtesy of Dr. Nagaraja et al. (Kansas State University)



Reproduced from http://www.shmoop.com/cell-respiration/glycolysis.html

Hydrogen sinks in the rumen



Morgavi DP, et al. Animal. 2010 Jul;4(7):1024-36.

Research Question

Beef Production is > 80% forage

Can dietary intervention be used to reduce methane in ruminants?

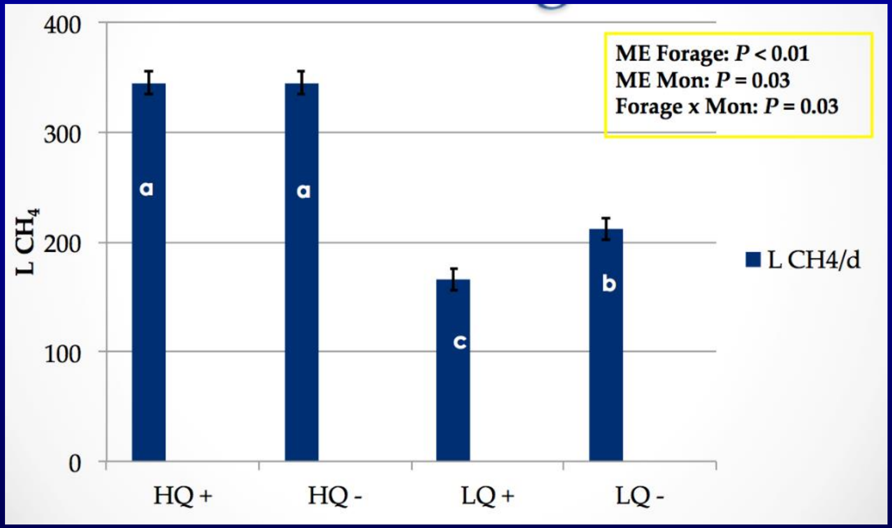
Growing Study

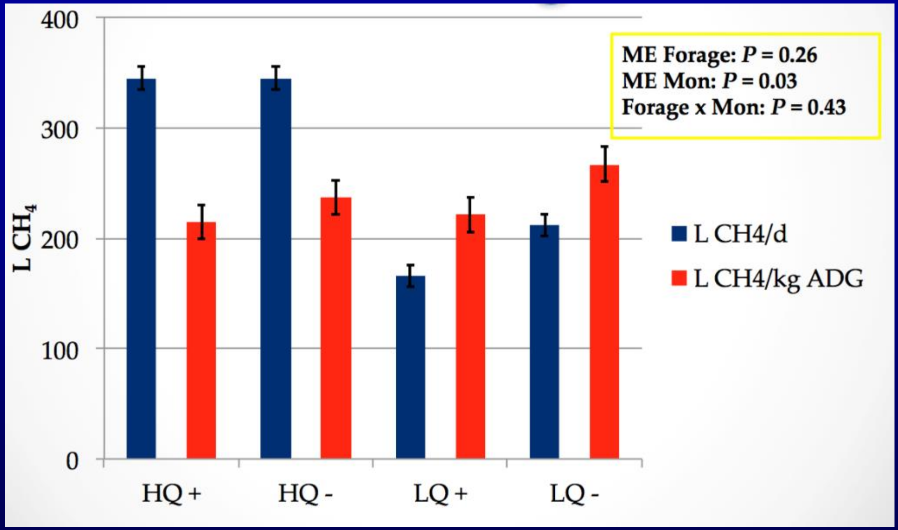
- 120 steers, initial BW 300 ± 25 kg
- 84 d growing study
- Forage quality:
  - High (alfalfa/sorghum silage)
  - Low (cornstalks)
- Monensin: +/-
- MDGS type and level:
  - Normal vs. De-oiled
  - 0, 20, 40%

S.C. Fernando et al.

Emissions: Forage x Mon.

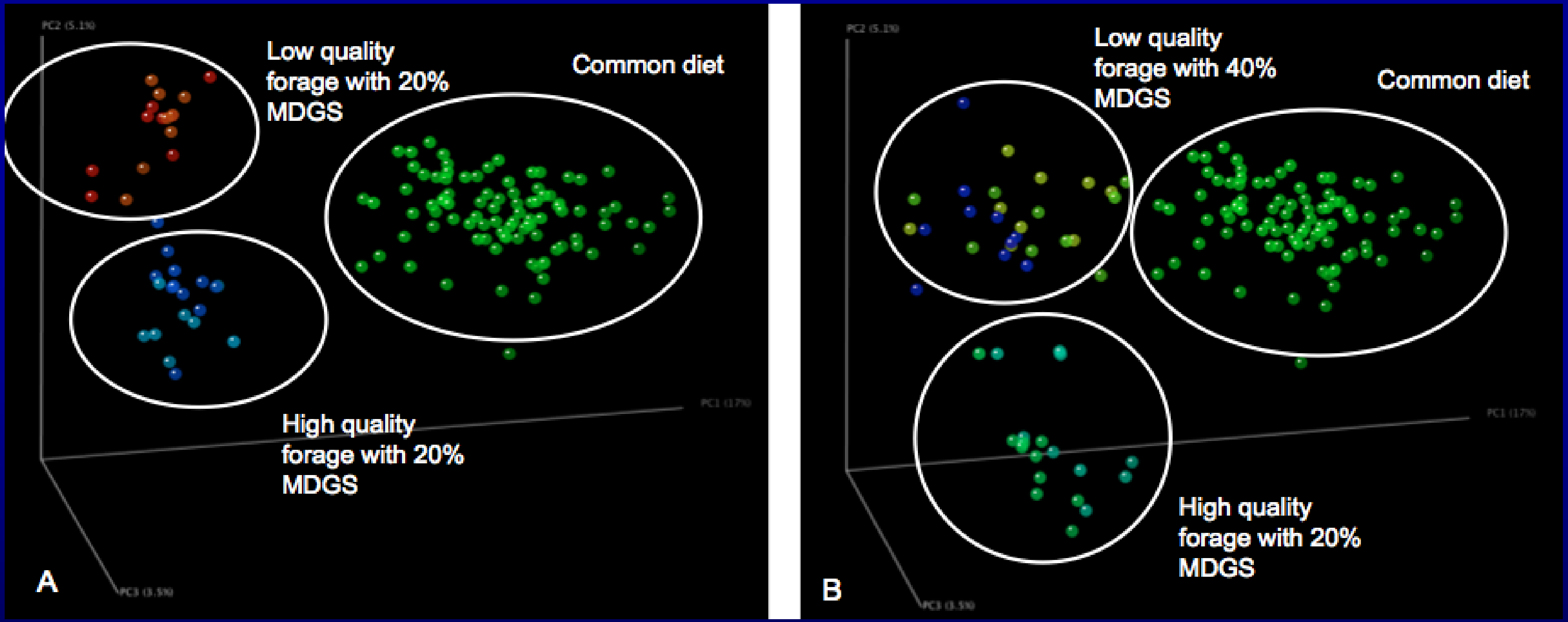
	40% De-Oiled MDGS							
	HQ		LQ			P-value		
Monensin	+	-	+	-	SEM	Forage	Mon.	Int.
$CH_4:CO_2$	0.101[a]	0.101[a]	0.083[b]	0.101[a]	0.003	<0.01	<0.01	<0.01





Pesta et al. Unpublished data

Structuring – Forage Quality
Bacteria



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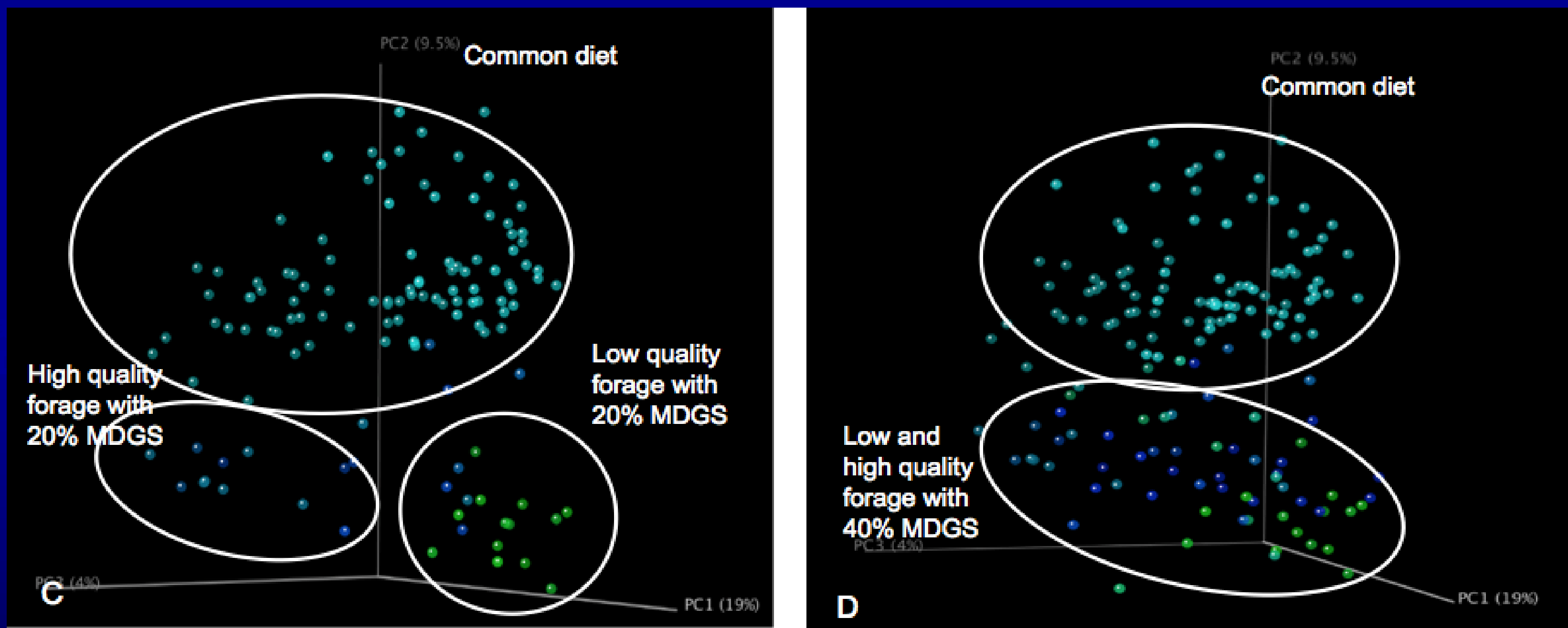
Knoell et al. Unpublished data

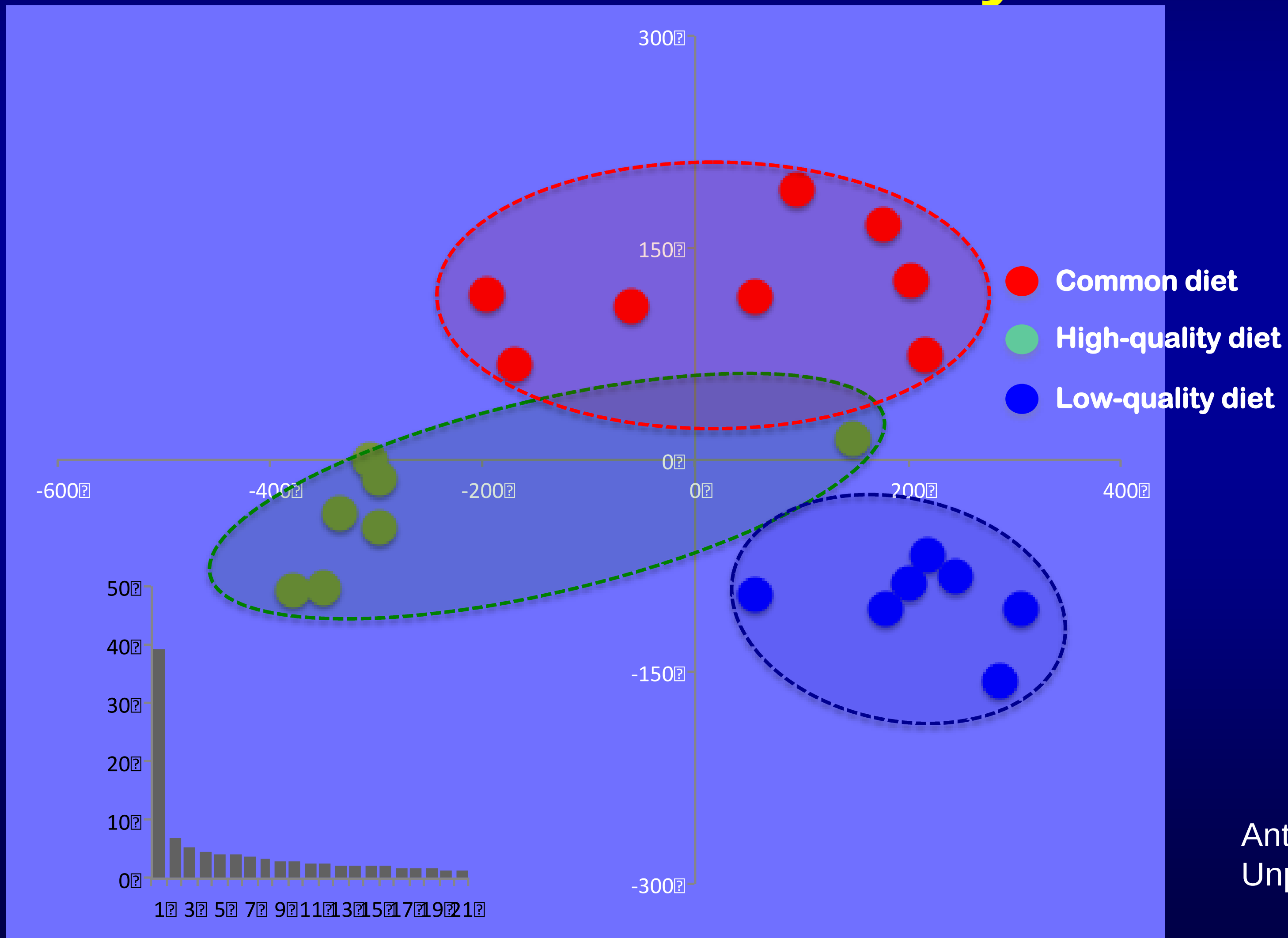
Structuring – Forage Quality
Archaea



Knoell et al. Unpublished data

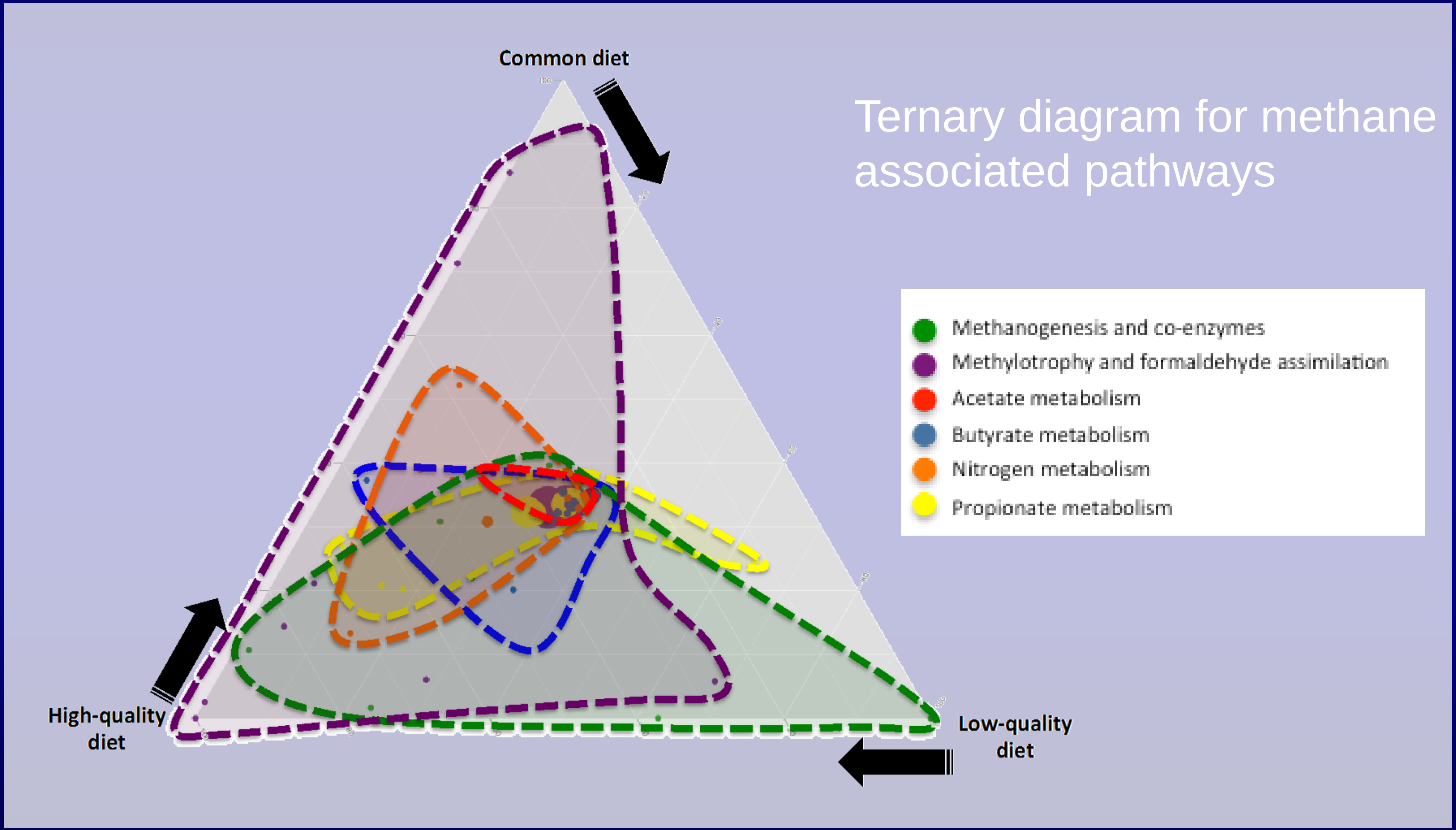
Metagenomic Analysis to Identify Microbial Pathways

Principle Component Analyses for all enzymes based on metagenomic shotgun analyses



Anthony-Babu et al.
Unpublished data

Metabolic differences in HQ and LQ forage diets



Anthony-Babu et al. Unpublished data

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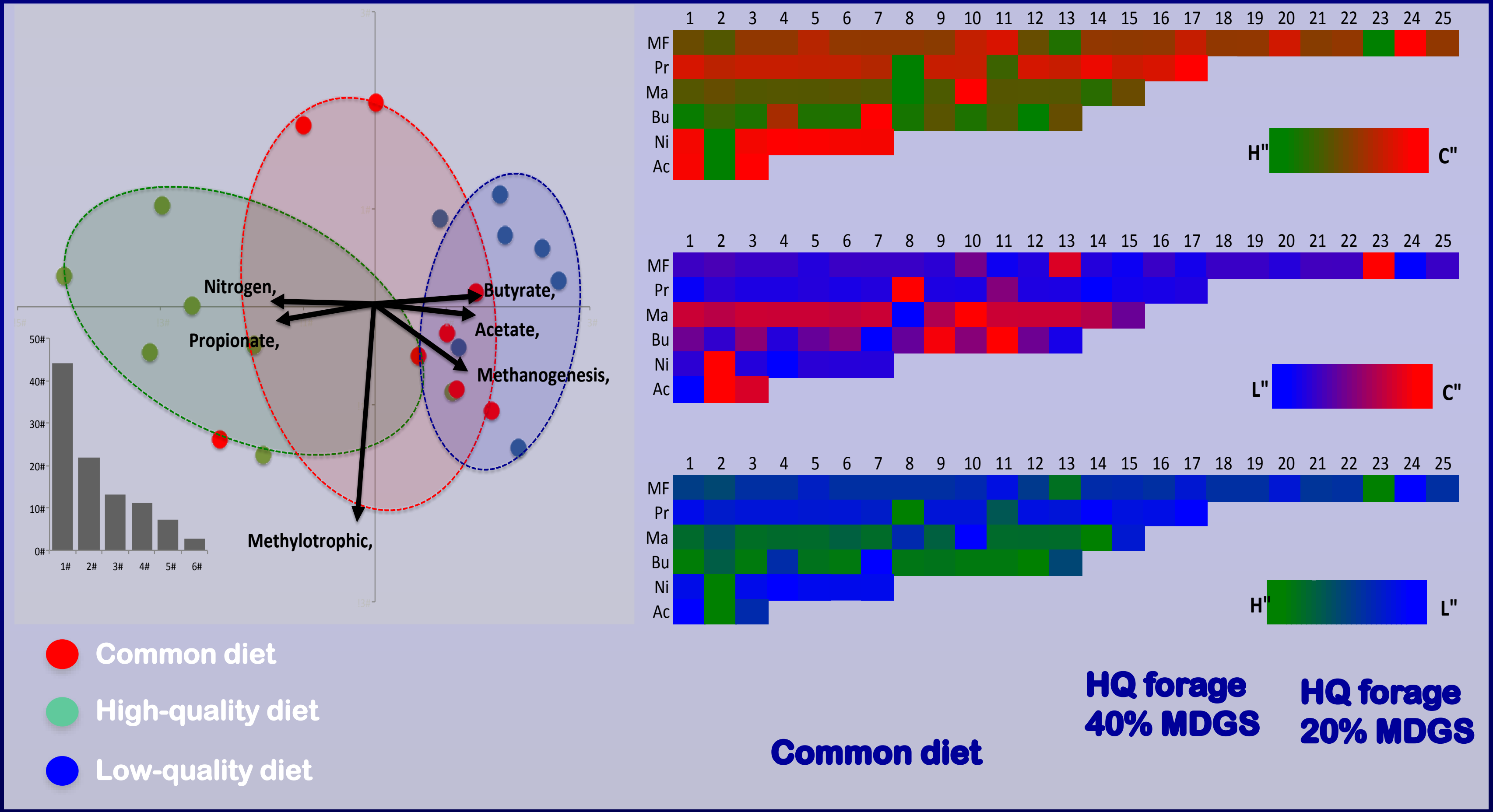


Anthony-Babu et al. Unpublished data

Key Points

- Production of methane within the rumen plays an important role in efficient substrate utilization
- Decreasing methanogenesis needs to be coupled with efficient rumen function
  - Re-cycling NADH using alternative pathways to methanogenesis
- Dietary intervention is a viable strategy to reduce enteric fermentation by utilizing substrates that select for microbes that compete with methanogens for H_2
- Whole rumen ecosystem needs to be considered

Beef Systems Research

- Evaluating how a change in one segment impacts production and profit in multiple segments

Seedstock producer

Commercial cow/calf

Backgrounding sector

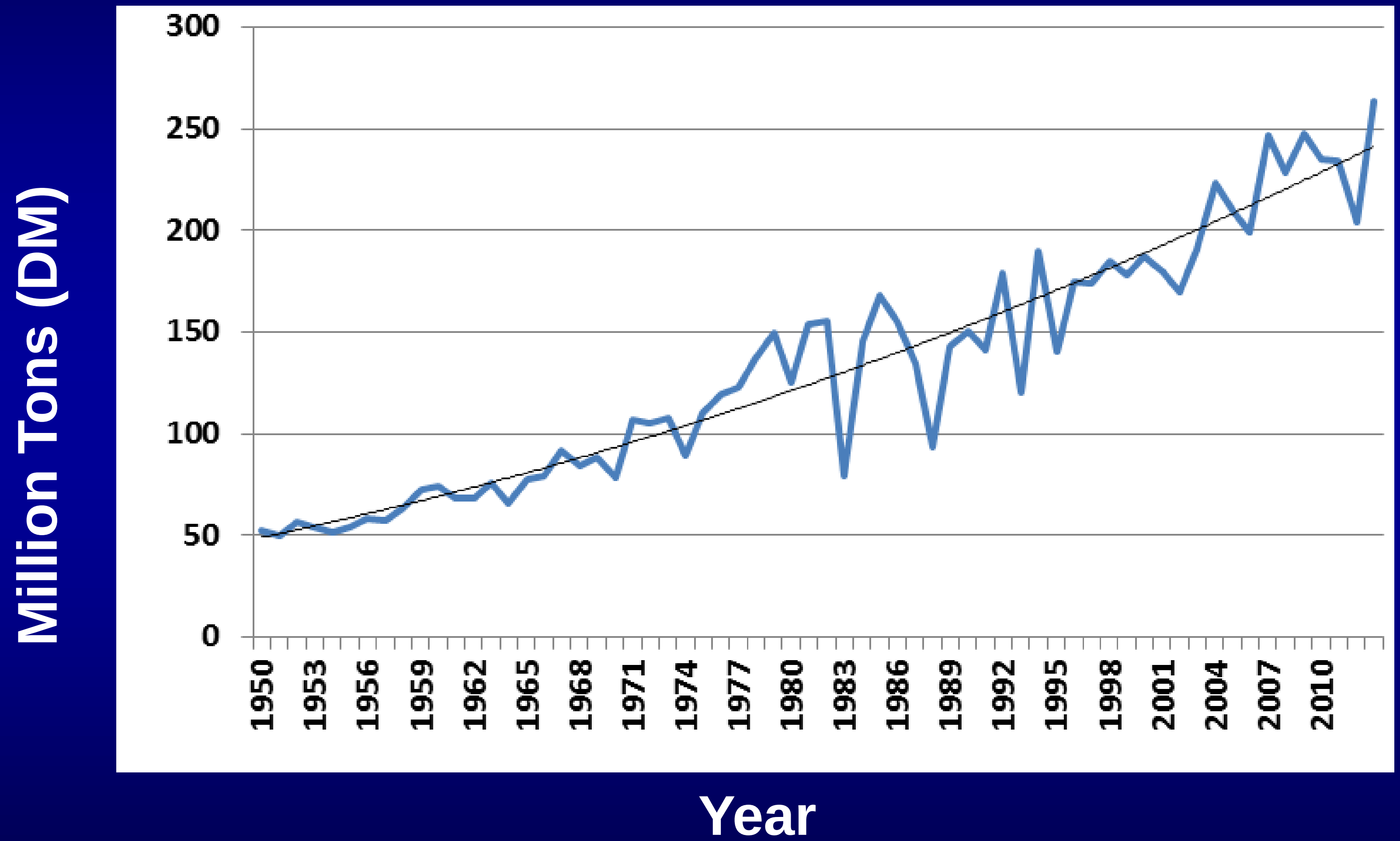
Feedlot sector

Packing industry

Retailer

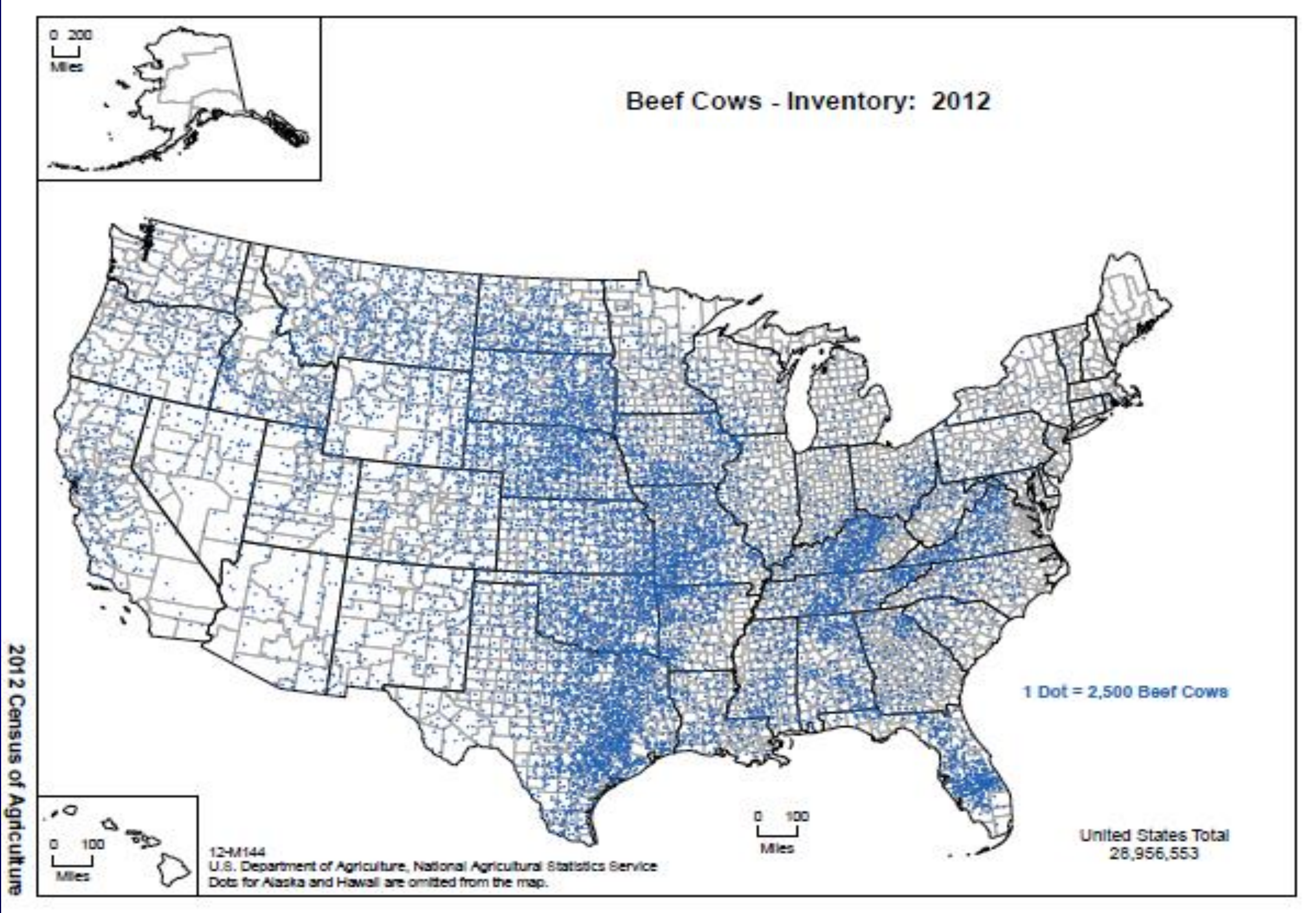
Consumer

Available corn residue 1950-2014



Assumes forage is 80% of corn yield, DM basis

Beef Cows


Beef Cows - Inventory: 2012
0 200
Miles
1 Dot = 2,500 Beef Cows
0 100
Miles
United States Total
28,956,553
0 100
Miles
12-M144
U.S. Department of Agriculture, National Agricultural Statistics Service
Dots for Alaska and Hawaii are omitted from the map.
2012 Census of Agriculture

Future Direction

- Should we encourage farmers to integrate cows onto existing farmland?
- Why? Pasture is limited and total production per acre increases.

Technologies

Method	% Improvement in FE
Implants	5 to 15%
Ionophores	4 to 8%
DFM	2 to 2.5%
β-adrenergic agonists	10 to 30%

Opportunities

- “Wide variation in environmental footprints found among individual production systems indicates that reductions can be made to improve overall sustainability.” (Rotz et al., 2019)
  - Will require improvements on individual operations
  - Decrease days on feed
  - Optimize use of fertilizer
  - More efficient use of solar and wind power for fencing and watering
  - Efficient use of water

Opportunities

- Increased understanding of GxExMxS
- Increased understanding of Genotype to Phenotype
- Emphasis on the use of precision management tools
- Place value of information flowing across segments of the industry
- Animal health and well being
- Consumer confidence and trust (social and product)

Conclusions

- Beef cattle rely on forages for production
- Diversity of microorganisms in the rumen allows for altering nutritional strategies to improve efficiency
  - Improve efficiency of forage utilization
- Byproducts and crop residue use important for competitive advantage
- Variation in environmental footprints indicate improvements should be individualized
- There is need for greater understanding of GxExMxS


From Pasture...
OSU
...To Plate

Beef cattle are well positioned

Questions ?