Nutritional strategies to enhance efficiency and sustainability of the US dairy industry

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USDA
National Institute of Food and Agriculture

FFAR
Foundation for Food and Agriculture Research

CDCB
COUNCIL ON DAIRY CATTLE BREEDING

MICHIGAN STATE UNIVERSITY
Michigan Alliance for Animal Agriculture

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Perfect Day

Our Story | Join Us | Say Hello | FAQs | Upd

Animal-Free | Our Process | Sustainability Benefits

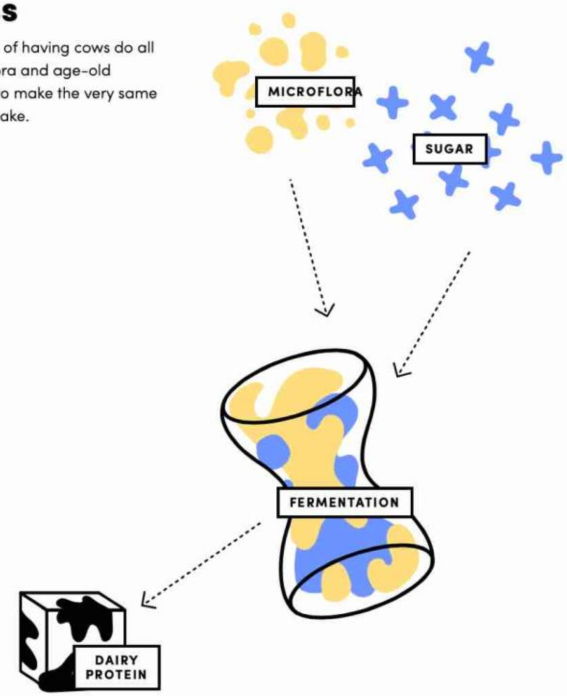
Why Animal-Free?

We wanted to enjoy the dairy foods we love without compromising on how they taste or our commitment to the environment.

We're creating a better way to make dairy protein – the same nutritious protein found in cow's milk. And we're doing it without the help of a single cow.

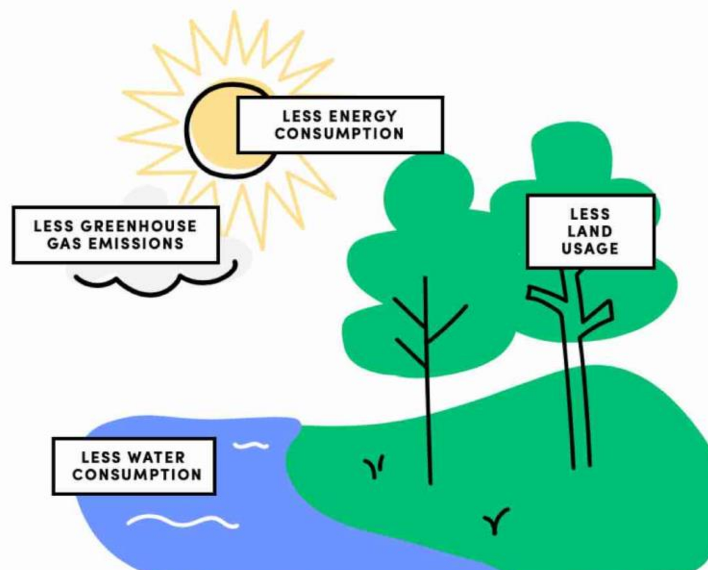
Our Process

How do we do it? Instead of having cows do all the work, we use microflora and age-old fermentation techniques to make the very same dairy protein that cows make.



A Smaller Hoofprint

Crafting dairy protein without cows means we can do more with less...



Forbes

Perfect Day Partners With ADM To Make Milk Without Cows

Lana Bandoim Contributor
Food & Drink
I write about food tech and science.

More exciting news from Perfect Day

"a quarter of all greenhouse gas emissions can be traced to the agriculture industry, with meat and dairy responsible for a whopping 60% of that. … the world's leading meat and dairy producers emit as much greenhouse gas as the world's top oil and gas giants"

"we want people to continue enjoying the dairy foods they love… without compromising our climate future. How? By efficiently making dairy protein through the fermentation of microflora, which requires fewer resources and emits substantially fewer emissions than factory farms.

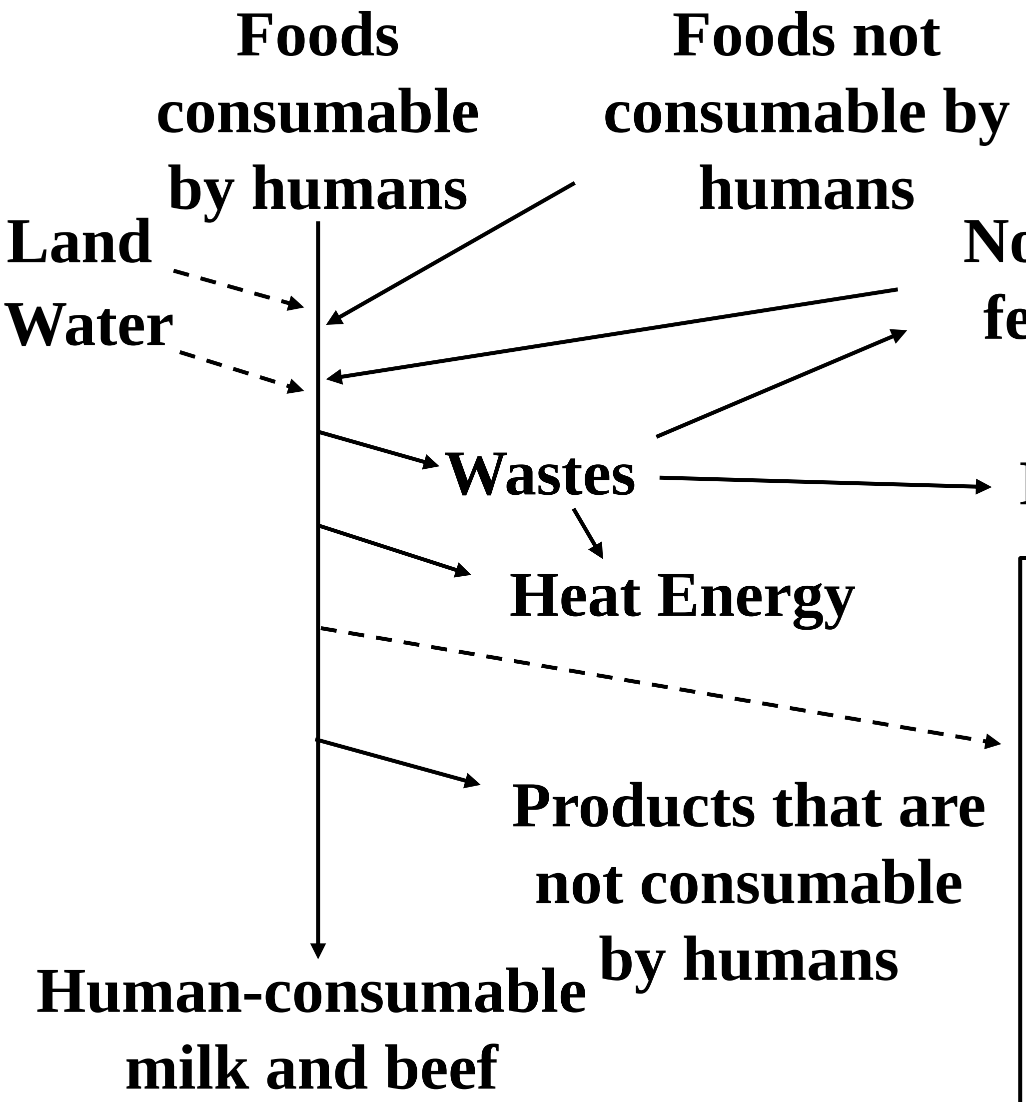
"tastes like dairy without any of the guilt"

Outline

- The basics of feed efficiency
- How are we doing now?
- What can we do next?
- What questions must be answered?

Ever-Green-View, 2/15/2010
2790 #F, 2140 #P in 365 d

Feed efficiency and sustainability



- *global climate impact*
- *farm profitability*
- *ecosystem services*
- *soil erosion and conservation*
- *imported oil*
- *rural aesthetics*
- *rural sociology*
- *food quality and healthfulness*
- *food security*
- *animal behavior and well-being*
- *efficiency of the beef industry*

One metric cannot do justice to the system!

A simpler scheme for feed efficiency

Gross Energy of Feed —(**Digestion/ Metabolism**)→ **Net Energy of Feed** —(**Dilution of maintenance**)→ **Energy captured as milk or body tissue**

Energy lost as feces, gas, urine, and heat for metabolizing feed

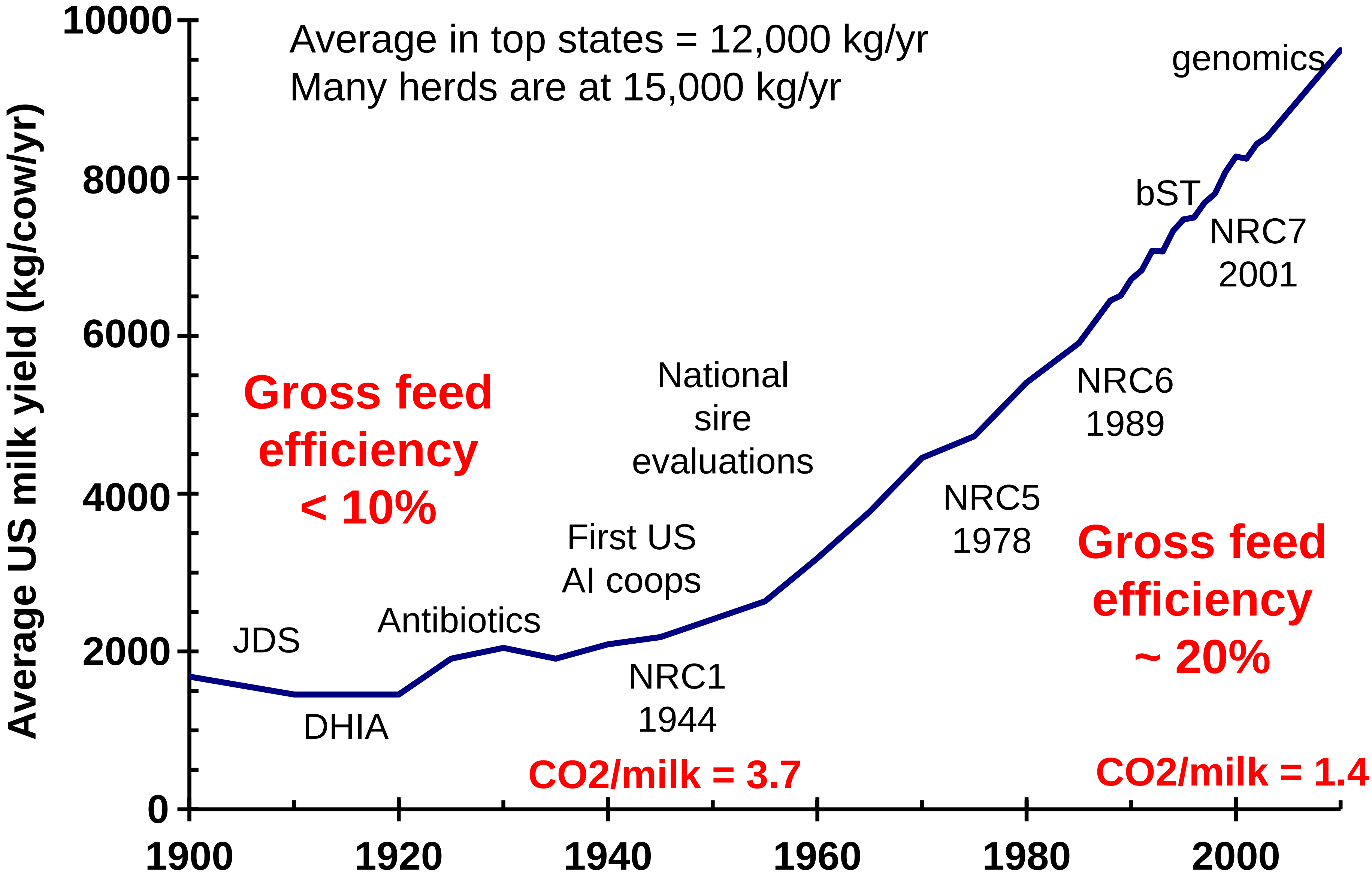
Energy lost as heat for maintenance

Gross feed efficiency is the percentage of feed energy captured in milk and body tissues.

To improve gross feed efficiency:

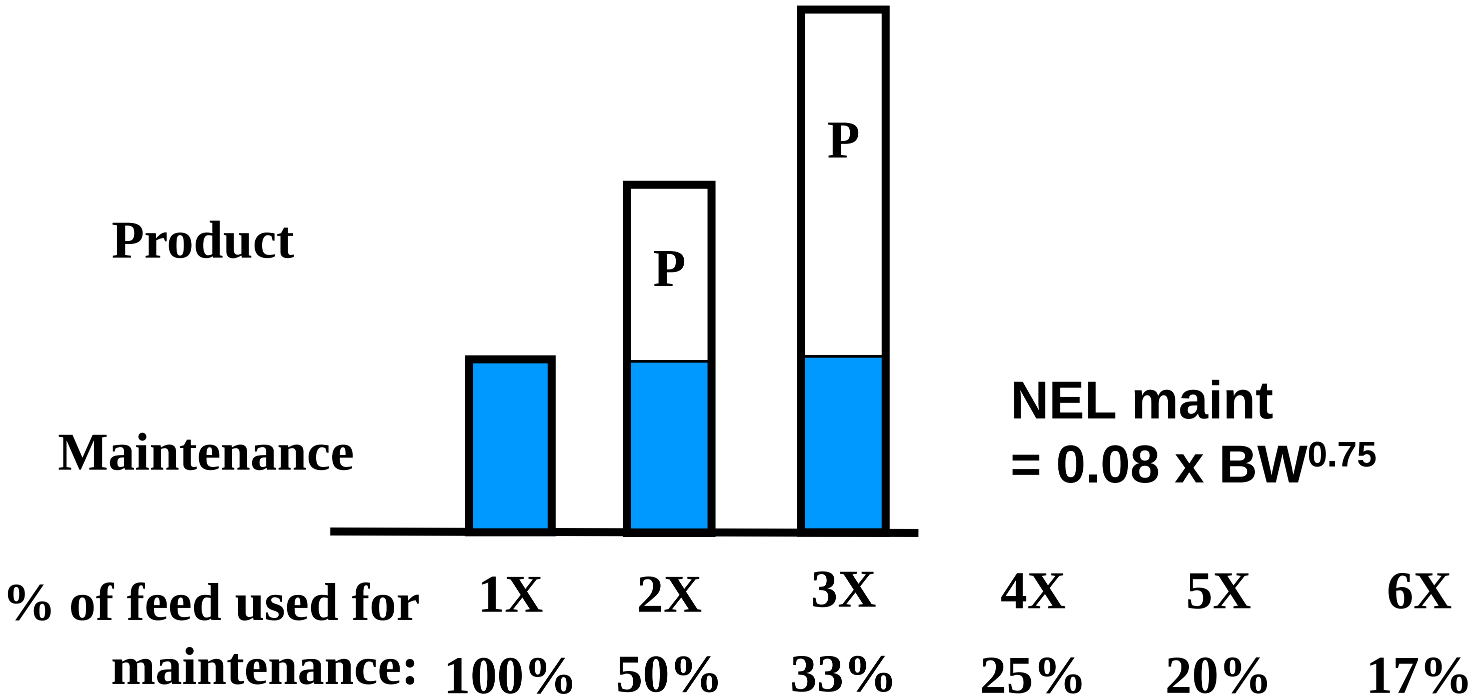
1. ***Increase the conversion of GE to NE***
   - ***Feed more digestible feeds in well-balanced diets***
2. ***Increase milk production relative to maintenance.***
   - ***Feed, breed, and manage for maximum production***

Increased productivity in the past has increased efficiency



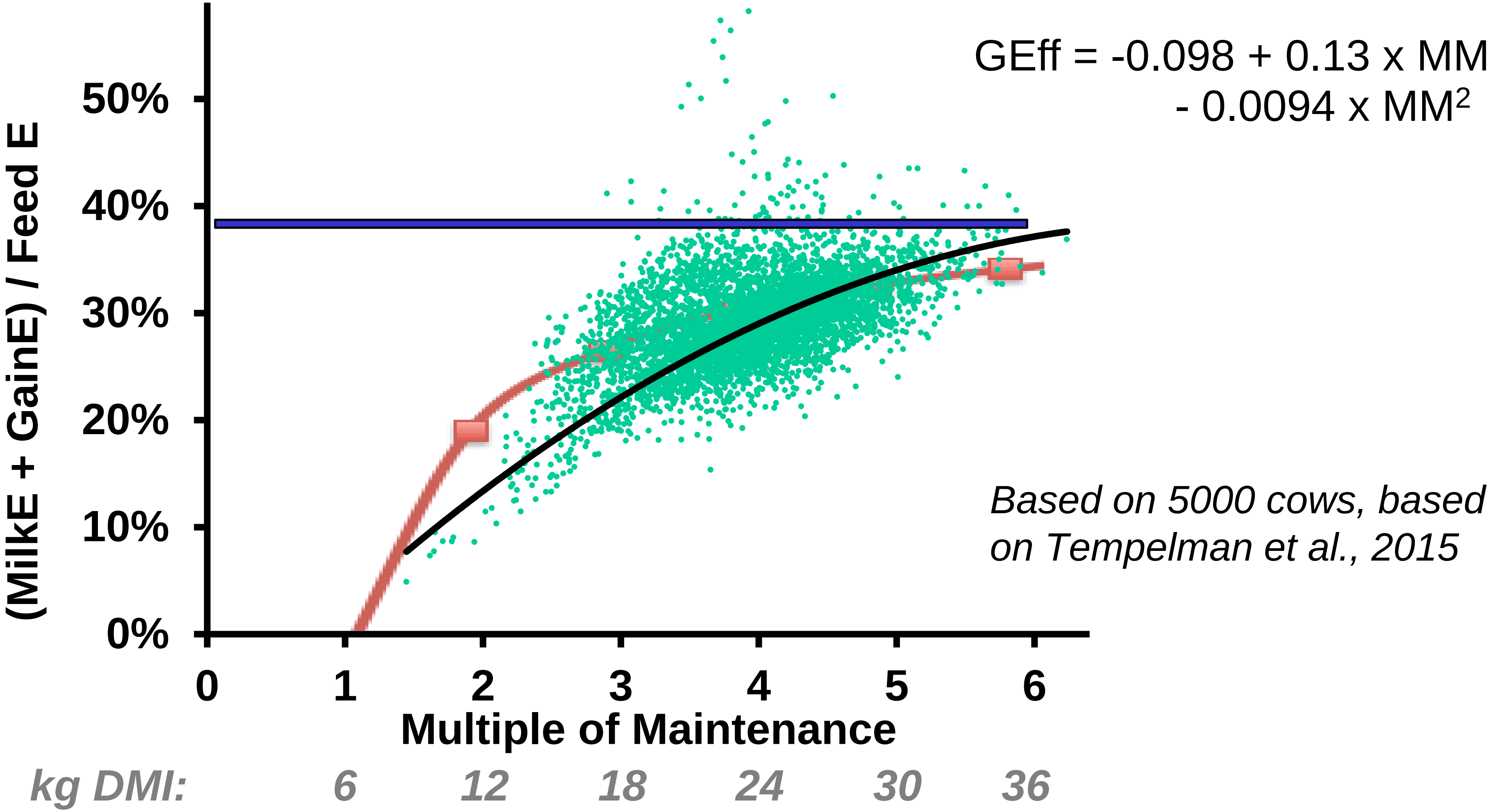
GHG emissions based on Capper et al., 2009

Efficiency increases from the "Dilution of Maintenance"



As cows eat more and produce more per day, a smaller percentage of the food they eat is used for maintenance and a greater percentage is converted to product.

Optimal production per unit BW based on current data



High producing cows per unit BW are more efficient.
The returns in efficiency from more milk are diminishing, but not as much as current NRC suggests!

Efficiency of land use in animal agriculture

The most efficient human diet would be eating lower on the food chain – cereal grains and legume seeds, supplemented with locally-grown (as in you can ride bike to buy them) vegetables, fruits, and the products of grazing or scavenging animals.

Efficiency of land use relative to corn and soybeans

Grazing dairy farm (5000 kg milk/yr)	40-50%
High producing confined dairy farm	
no byproduct feeds	40-50%
with byproduct feeds	80-100%

From *VandeHaar and St-Pierre, 2007, J Dairy Science*

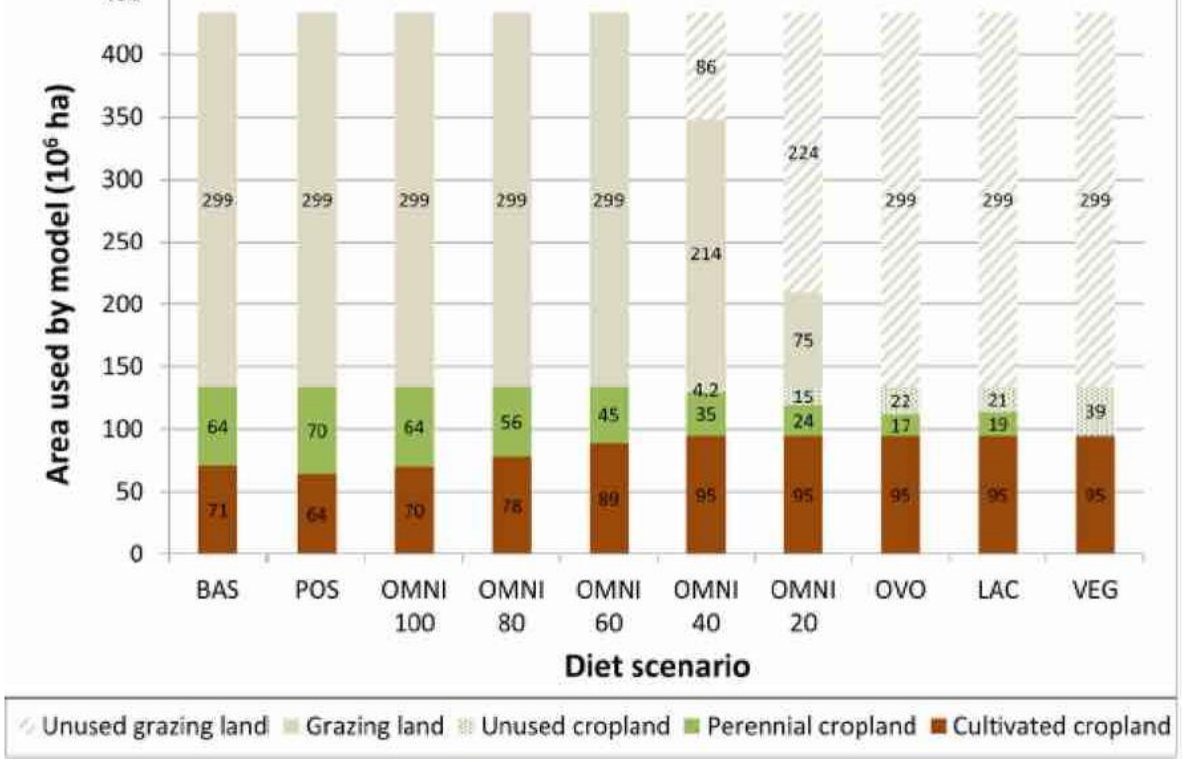
The amount of land used to produce food is 10-20% less for a person eating only grains and legume seeds than a person eating dairy products from well-managed modern dairy farms.

Diet choices and land use

Lactovegetarian, ovovegetarian, and omnivore diets of mostly plants fed more people per unit of land than a strictly vegan diet.

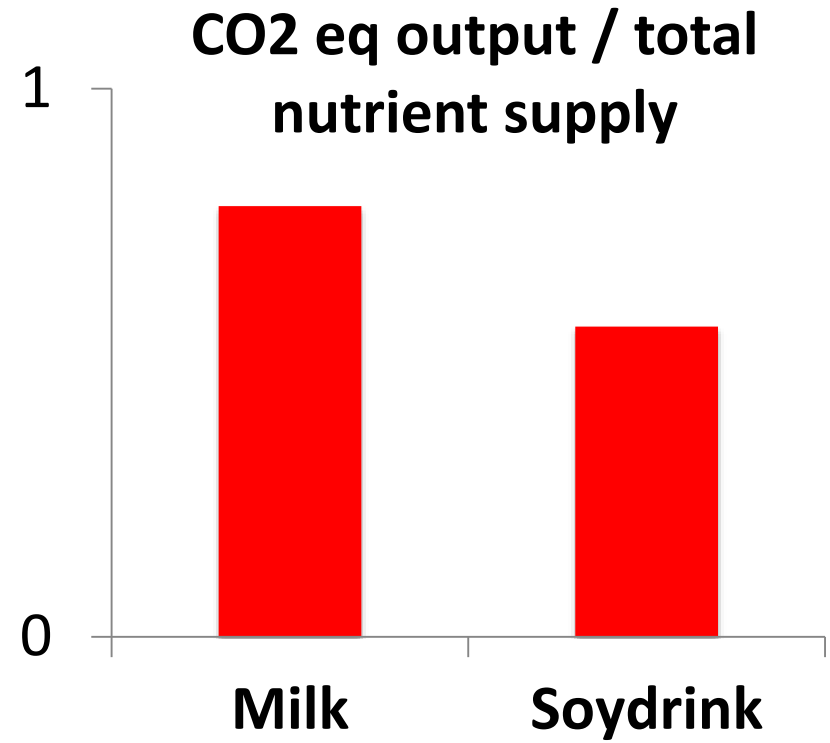
Some land is not suited for growing plants for human consumption is better used for grazing.

Peters et al., 2016. Carrying capacity of U.S. agricultural land: Ten diet scenarios. Elementa: Science of the Anthropocene 4:1-15.



Scenario	Population fed	
Symbol	(10^8 persons)	(% of 2010 population)[a]
BAS	4.02	130%
POS	4.21	136%
OMNI 100	4.67	151%
OMNI 80	5.48	178%
OMNI 60	6.69	217%
OMNI 40	7.52	244%
OMNI 20	7.69	249%
OVO	7.87	255%
LAC	8.07	261%
VEG	7.35	238%

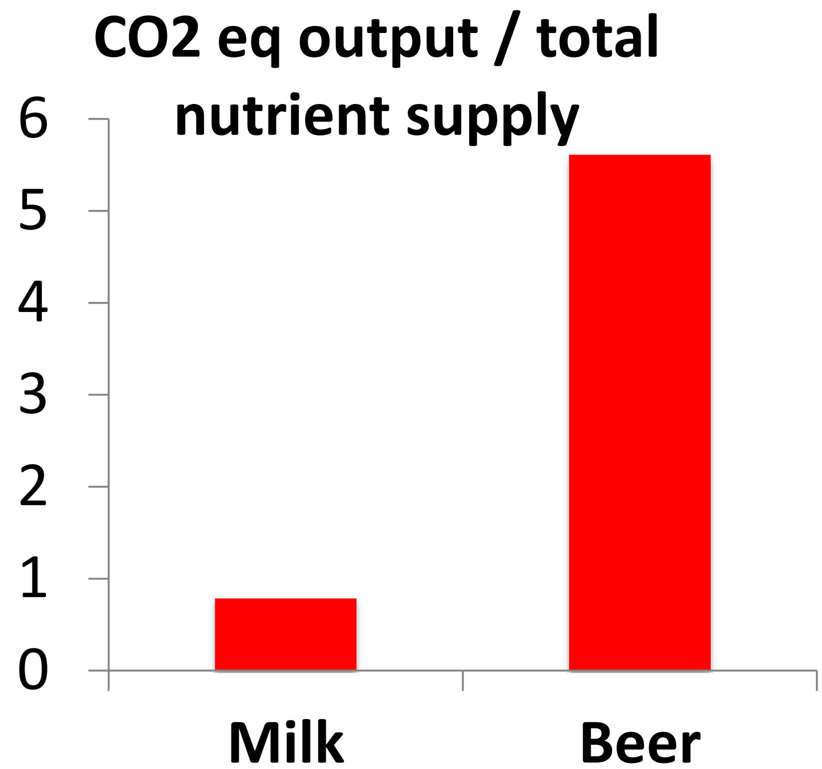
Greenhouse gas emissions relative to nutrient supply



Greenhouse gasses are slightly greater for dairy, but dairy products are still a good food choice!

based on Smedman et al., 2010

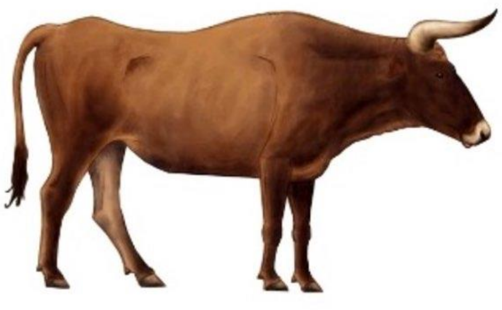
Greenhouse gas emissions relative to nutrient supply



Dairy products fit with a sustainable future

based on Smedman et al., 2010

We have made a lot of progress in 9000 years!



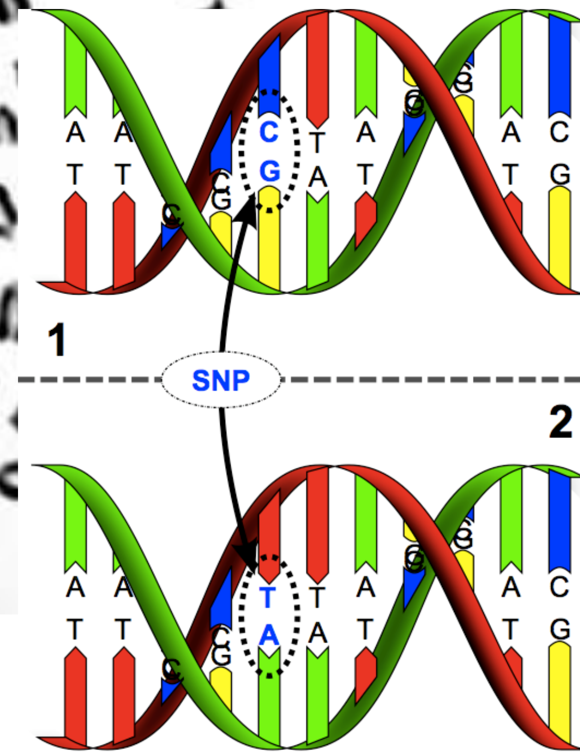
Eurasian auroch

Ever-Green-View, 2/15/2010
2790 #F, 2140 #P in 365 d

Most of the change has been through the dilution of maintenance. Cows have more mammary tissue. Diets contain more grain. Management is intensive.

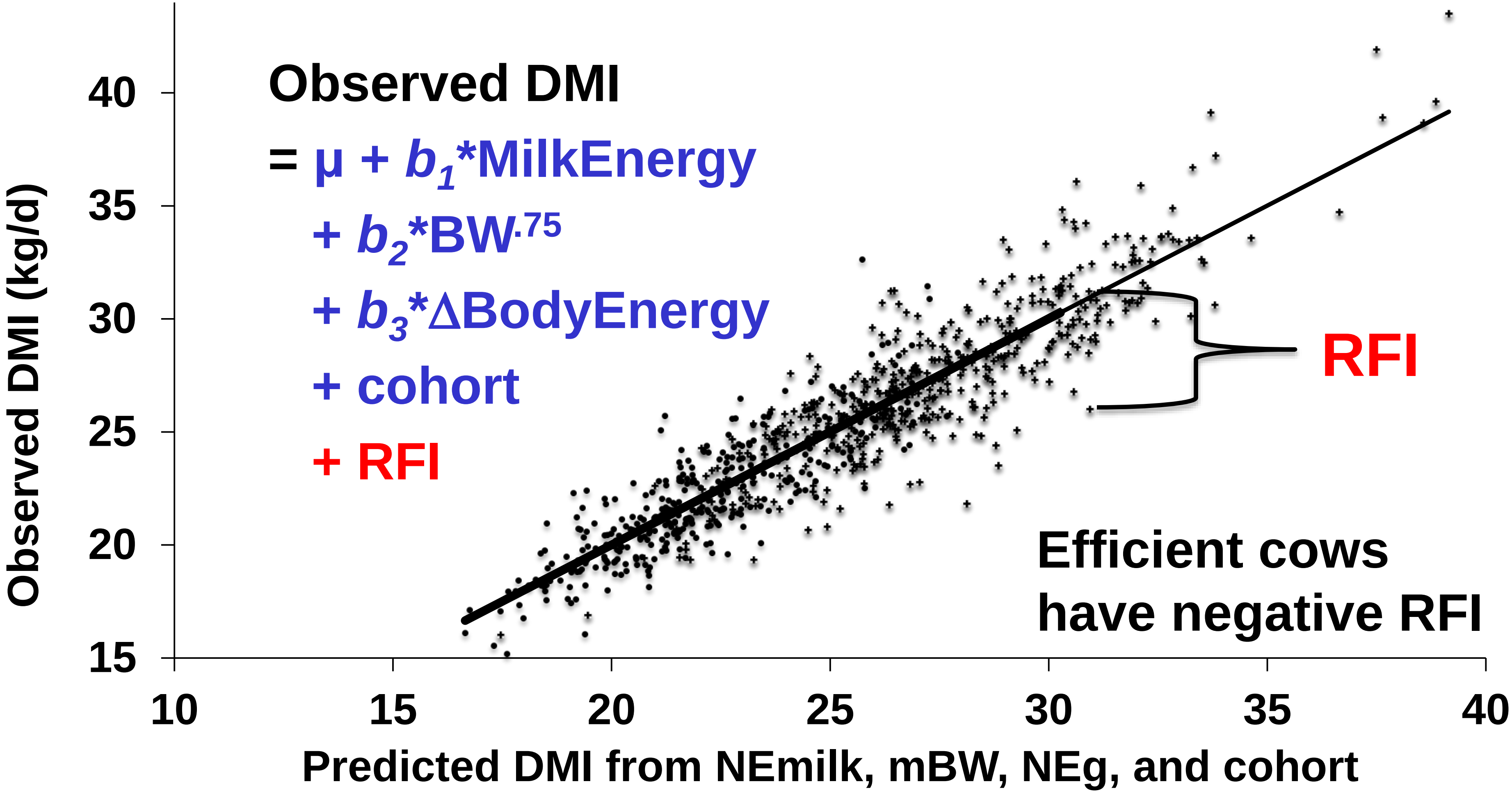
What can we do to make further improvements?

2 sets of 30 chromosomes,
with 3 billion base pairs per set



We can select for greater efficiency, health, longevity, adaptability, digestive capacity for fiber, and more!

Residual feed intake (RFI) = "unjustified" feed intake



RFI is heritable (0.17) and repeatable across diets, lactations, and climates. *(Tempelman et al., 2015; Potts et al., 2015)*

Genomic BV for efficiency will soon be used in the US.

Managing for greater feed efficiency

1. Feed efficiency is useful on farms, but the financial return to each feed is what matters most.

- Some expensive feeds, such as fats, may increase feed efficiency but not be worth the cost. Many high fiber feeds will decrease feed efficiency but be worth feeding anyway.

2. Feeding cows to meet their potential without overfeeding is key.

- Ad lib TMR feeding has increased milk production but decreased the focus on individual cows.
- Nutritional grouping can help.
- Can we use computerized systems to feed cows as individuals?

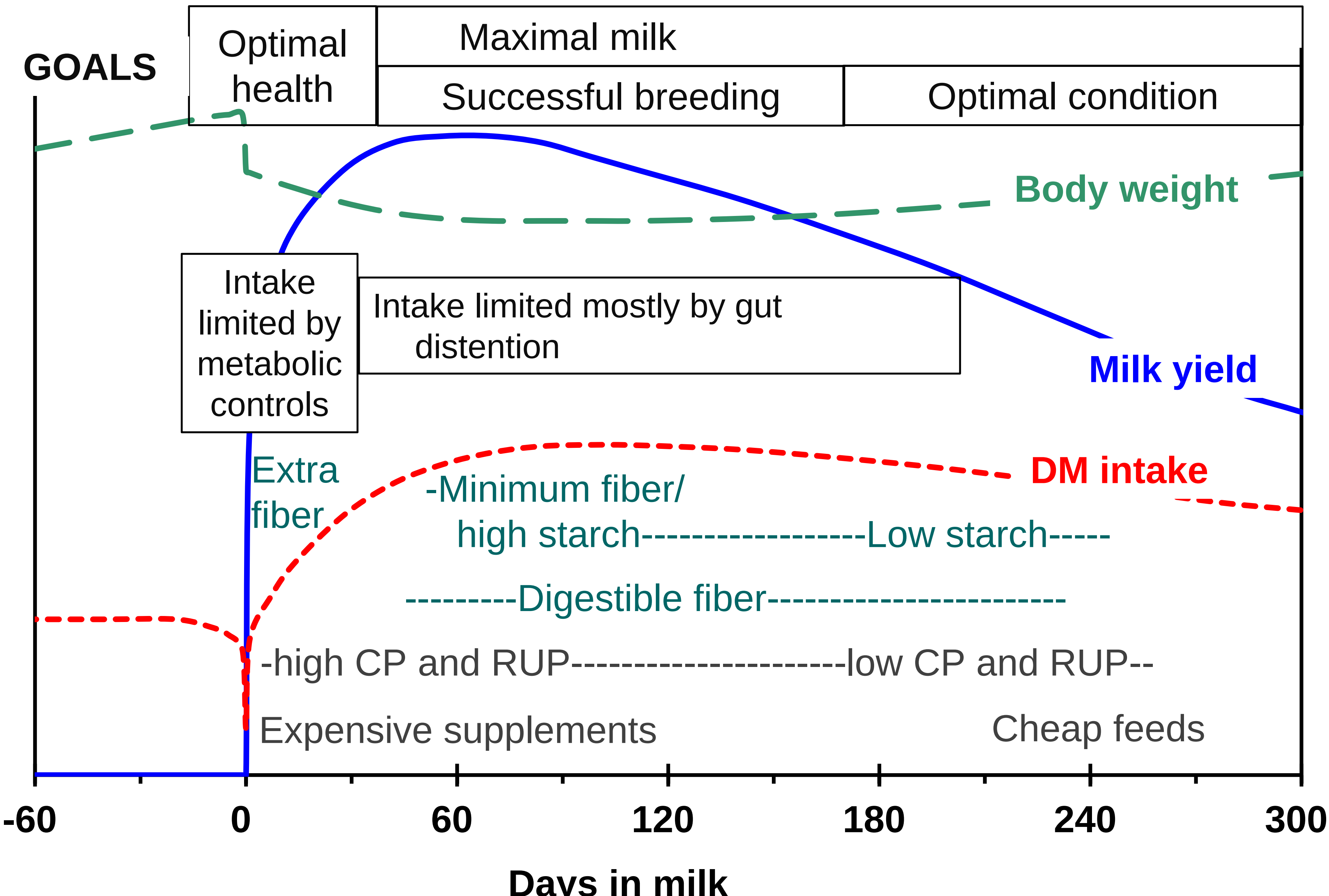
Impact of selected management changes on energy and protein efficiency for a farm with 10,000 kg milk/cow/year

	Energy	Protein
Base feed efficiency for whole farm	21%	28%
Increase milk production 10% (1000 kg/year)	+0.7%	+0.4%
Increase longevity from 3 to 4 lactations	+0.6%	+0.5%
Reduce age at first calving 2 months	+0.3%	+0.3%
Reduce calving interval 1 month	+0.4%	+0.4%
Feed cows >150 DIM a diet with 2% less CP	+0.0%	**+1.3%**
Reduce feed wastage 10%	+2.3%	+3.1%

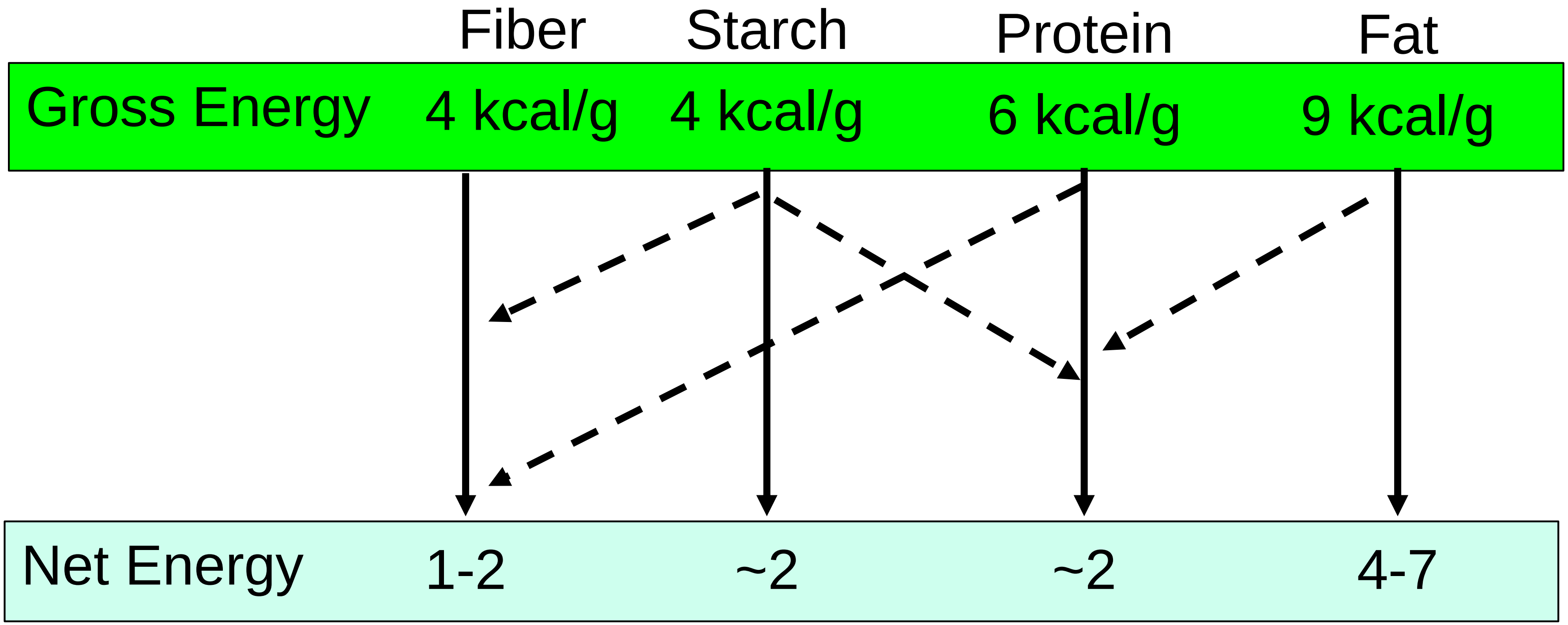
based on the model used in VandeHaar, 1998, JDS.

Grouping cows for better management and feeding can help with all of these!

We need to stress the value of feeding by stage of lactation



Balancing nutrients to enhance efficiency



- ***Nutrients serve as precursors for synthesizing products.***
- ***Nutrients also interact to alter digestion, feed intake, and nutrient partitioning.***
- ***Maximizing efficiency of both protein and energy at the same time is nearly impossible.***
- ***Responses to diet changes must be monitored!***

Effect of intake and dietary starch on digestion and allowable milk

DMI kg/d	Dietary Starch	Dietary NDF	Predicted StarchD	Predicted NDFD	Predicted Diet NEL Mcal/kg	NEL-available 3.7%Fat-Milk kg/d
Effect of increasing intake with 26% starch diet						
18	26%	36%	93%	47%	1.60	20
25	26%	36%	92%	46%	1.59	36
32	26%	36%	91%	45%	1.57	51
Effect of increasing starch or NDFD at DMI of 3.5% of BW						
25	20%	42%	92%	50%	1.54	34
25	26%	36%	92%	46%	1.59	36
25	34%	28%	92%	41%	1.67	38
25	26%	36%	92%	56%	1.66	38
Effect of increasing base digestibility and intake in combination						
18	18%	44%	93%	52%	1.54	19
25	26%	36%	92%	46%	1.59	36
32	34%	28%	91%	40%	1.65	54
32	26%	36%	91%	55%	1.65	54
35	34%	28%	91%	49%	1.70	65

Effect of intake and dietary starch on feed efficiency

DMI kg/d	Dietary Starch	MilkE /Feed GE	MilkE /HE GE	MilkE /Feed HME	MilkE /GasE	MilkE /HeatOutput
Effect of increasing intake with 26% starch diet						
18	26%	19%	56%	33%	2.8	0.52
25	26%	24%	69%	41%	3.5	0.76
32	26%	26%	77%	45%	3.9	0.93

Effect of increasing starch or NDFD at DMI of 3.5% of BW						
25	20%	23%	76%	43%	3.3	0.74
25	26%	24%	69%	41%	3.5	0.76
25	34%	26%	64%	38%	3.9	0.80
25	26%	26%	75%	44%	3.7	0.79

Effect of increasing base digestibility and intake in combination						
18	18%	18%	62%	35%	2.5	0.49
25	26%	24%	69%	41%	3.5	0.76
32	34%	28%	70%	42%	4.3	0.97
32	26%	28%	82%	48%	4.1	0.96
35	34%	30%	75%	46%	4.5	1.06

Predicting intake responses is key to optimizing diets

<u>Intake prediction without feed factors.</u>

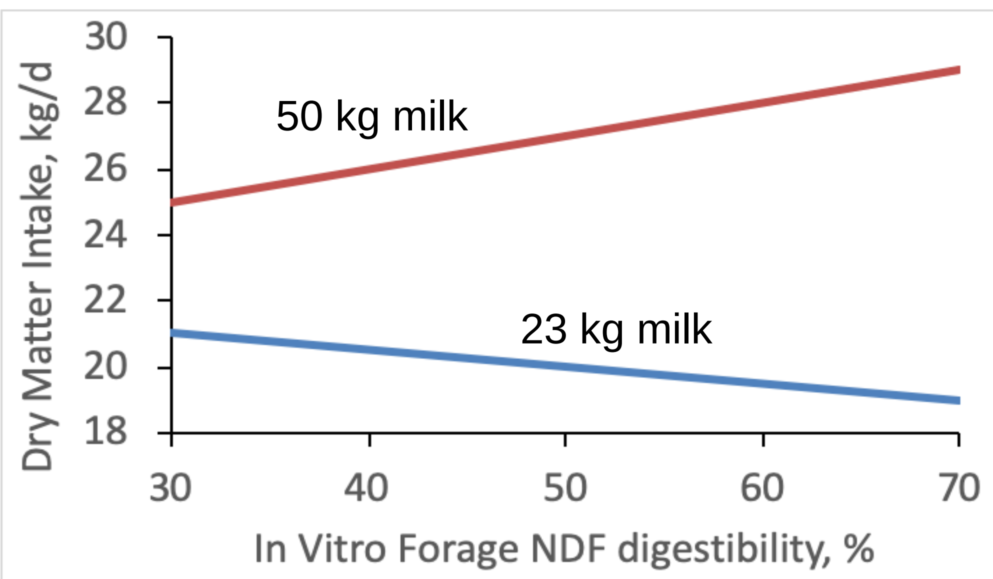
DMI (kg/d) = [3.7 + 5.7 x Parity + 0.305 x MilkE + 0.022 x BW + (- 0.689 -1.87 x Parity) x BCS] x [1 – (0.212 + Parity* 0.136) * $exp^{(-0.053*DIM)}$]

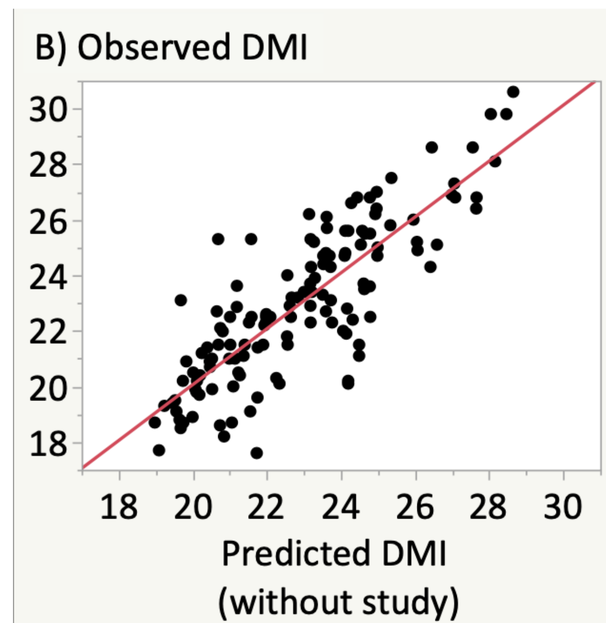
- Souza et al., JDS submitted

<u>Intake prediction with feed factors</u>

DMI (kg/d) = 12 + 0.225(MY) - 0.106(FNDF) + 8.17(ADF/NDF) + 0.025(FNDFD) – 0.328(ADF/NDF–0.602)(FNDFD-48) + 0.0039(FNDFD-48)(MY–33)

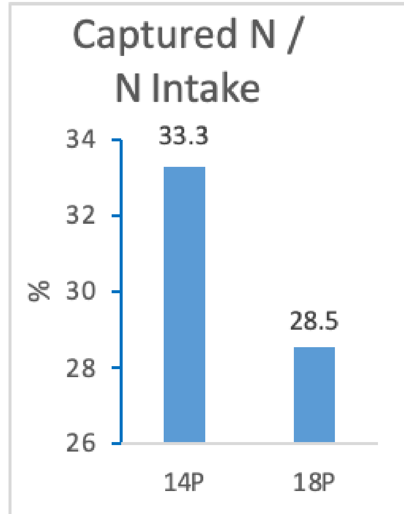
- Allen et al., JDS submitted

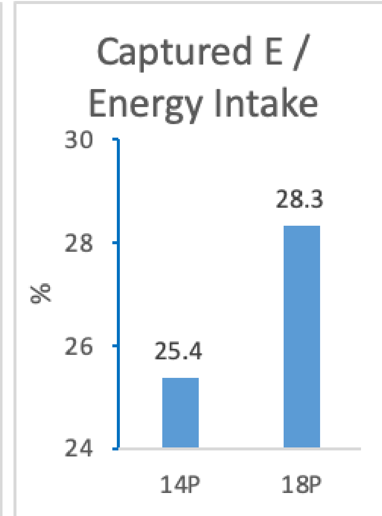


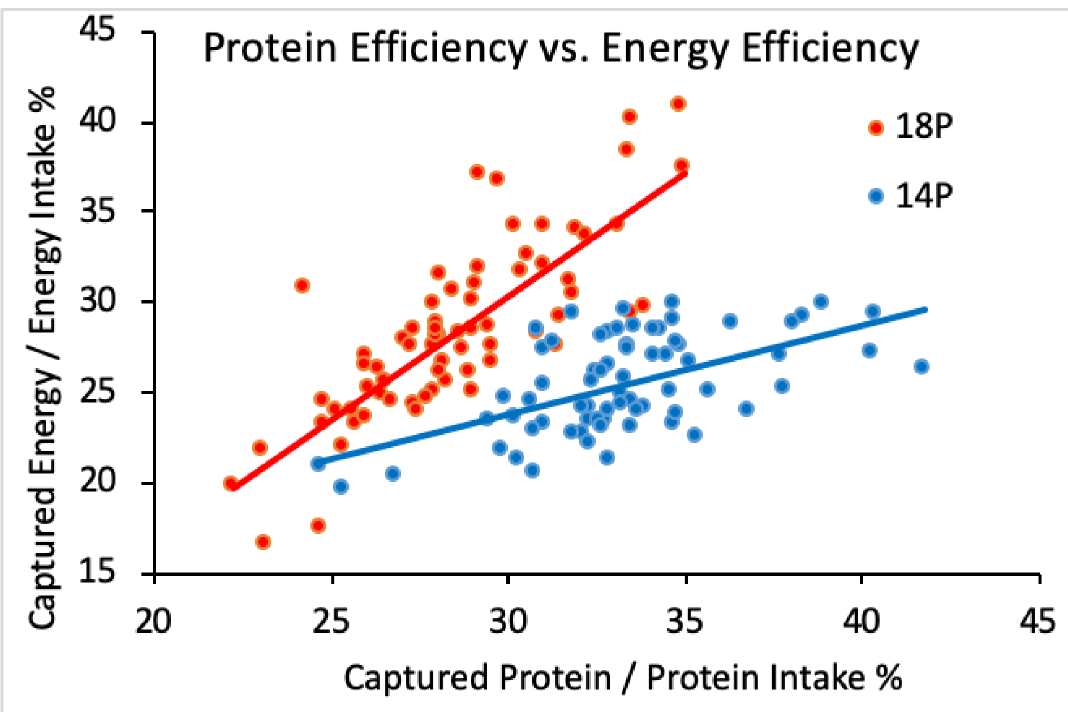


Trade-offs in optimizing protein and energy efficiency

170 Holstein cows in mid-lactation fed 18 or 14% CP diets in two 28-d treatment periods.





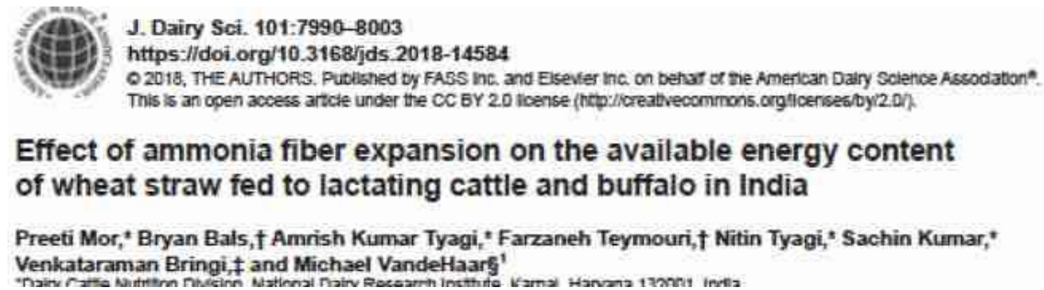


Balancing protein sources and perfecting bypass AA blends will help optimize both protein and energy efficiency at the same time.

Better methods for monitoring responses on farms are needed. They must include BW response.

Improving the use of crop residues to produce milk

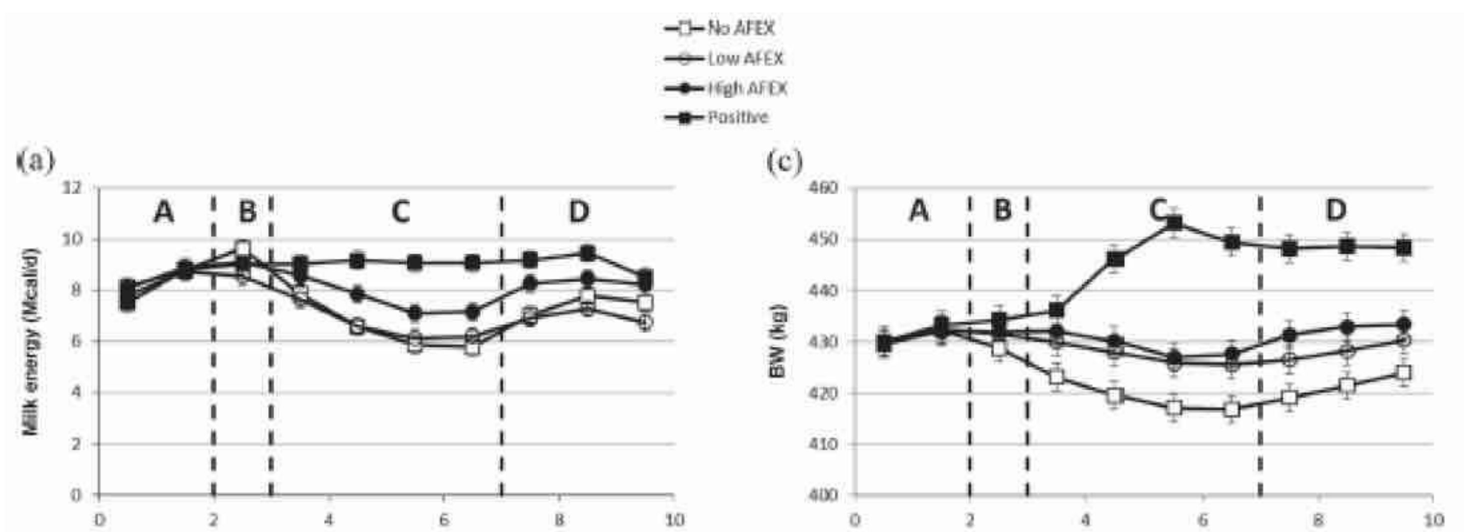
Ammonia-Fiber Expansion (AFEX) is process that enhances the digestibility of poor quality cellulosic materials.



J. Dairy Sci. 101:7990–8003
https://doi.org/10.3168/jds.2018-14584

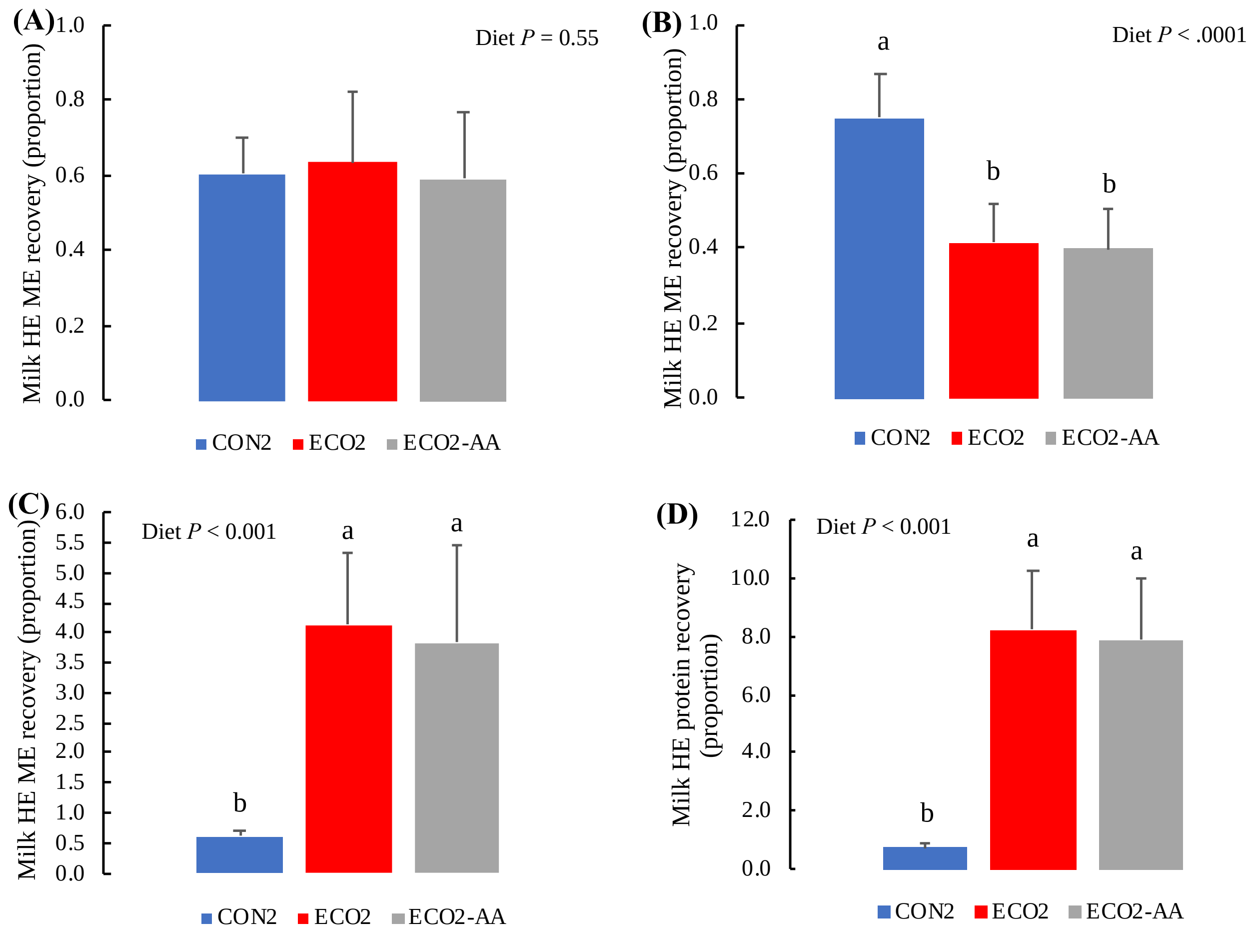
Effect of ammonia fiber expansion on the available energy content of wheat straw fed to lactating cattle and buffalo in India

Preeti Mor,* Bryan Bals,† Amrish Kumar Tyagi,* Farzaneh Teymouri,† Nitin Tyagi,* Sachin Kumar,* Venkataraman Bringi,‡ and Michael VandeHaar§[1]
*Dairy Cattle Nutrition Division, National Dairy Research Institute, Karnal, Haryana 132001, India



Using “ecological leftovers” to enhance efficiency.

Human-edible (HE) nutrient conversion rate of cows fed a conventional diet or a by-product-based diet either in a thrift scenario (top panels) or in a choice scenario (bottom panels). Thrift scenario considered hominy feed and wheat middlings as suitable foods for humans, whereas choice scenario did not.



Takiya et al., in progress (Kansas State)

“Ecological Leftovers” can improve conversion of human-edible nutrients from feeds into milk if you assume people won’t eat them.

Summary

- The rumen is an amazing bioprocessor and the mammary gland is an amazing factory.
- Animal breeding is producing more efficient cows, faster.
- Better grouping management can enhance efficiency.
- Computers and sensor technologies will enable us to manage cows more as individuals within group settings.
- New models are better at predicting responses to dietary changes.
- Efficiency has many facets and it is impossible to maximize efficiency of everything.
- New technologies will enable conversion of crop residues into more digestible and useful feeds for ruminants.
- Use of ecological leftovers (byproducts) will enhance availability of food for people.

Research challenges
(with help from NC-2040 colleagues)

- We must develop models to balance the trade-offs in efficiency.
- We need better models to make decisions that consider “non nutritive” effects of nutrients (such as effects on intake, partitioning).
- We need sensors to monitor individual cows in groups to 1) help answer fundamental questions, and 2) manage for efficiency
- We should try to improve ruminal digestion and decrease methane.
- We must do a better job of translating basic work to deployment on farms. USDA funding tends to look at projects as research OR extension. Sometimes this impairs the bridge between them.
- We must invest in more long-term studies to see if we really should extrapolate findings from 3-wk studies to whole lactations.
- We must consider the connections between dairy and beef systems.
- We must help consumers understand the choices available to them about food to avoid undesirable long-term consequences.
- We need to consider genetics in all these questions.

Discussion?

Funding was provided by Agriculture and Food Research Initiative Competitive Grant no. 2011-68004-30340 from the USDA National Institute of Food and Agriculture.