The US Dairy Feed Efficiency Database
Mike VandeHaar
Rob Tempelman
Kent Weigel
Grant Number 2011-68004-30340: Genomic Selection and Herd Management to Improve Feed Efficiency of the Dairy Industry

Goal: to increase the efficiency and sustainability of producing milk.

Specific aims:

1) develop a database of 8000 genomically characterized Holstein cows.
2) determine the genetic architecture of feed efficiency.
3) facilitate implementation of genomic selection programs for efficiency.
4) develop decision support tools to improve efficiency of the whole herd.
5) educate students about key practices that promote efficiency.

Nutrition: M VandeHaar (MI), L Armentano (WI), M Hanigan (VA), C Staples (FL), D Beede (MI), R Shaver (WI), J Dijkstra (NL)

Genetics: R Tempelman (MI), K Weigel (WI), D Spurlock (IA), R Veerkamp (NL), M Coffey (SAC), Z Wang (Alb), E Connor, G Wiggans (USDA)

Management: V Cabrera (WI), M Worku (NC), M Nielsen (MI), M Wautiaux (WI), R Pursley (MI), B Simpson (GeneSeek)
Outline and goals

Outline

1. The basics of feed efficiency and why it matters.
2. Relationships to level of production and body size
3. A summary of our project findings.
4. Where we are headed.

Ever-Green-View, 2/15/2010
2790 #F, 2140 #P in 365 d
The modern dairy cow is a different beast!

- We have been altering cattle genetics for 9000 years.
- Most selection was made based on animal’s own phenotype.
- Population genetics (>1937) accelerated the progress.
- We made a lot of progress based on looks and a few numbers.
- Modern dairy cows are taller, thinner, and less muscular, and they have bigger udders.
- Today we have data. Lots of it.
Increased productivity in the past has resulted in increased efficiency. Our focus to increase milk yield has increased feed efficiency indirectly through the dilution of maintenance.

- Increased milk yield from 1900 to 2000
- Gross feed efficiency:
  - < 10% before 1978
  - ~ 20% after 1978
- CO2/milk:
  - 3.7 before 1978
  - 1.4 after 1978

Key events:
- JDS: 1944
- DHIA: 1944
- NRC1: 1944
- Antibiotics: 1944
- First US AI coops: 1944
- National sire evaluations: 1945
- NRC5: 1978
- bST: 2001
- NRC6: 1989
- NRC7: 2001
Feed efficiency is a complex trait.

- Climate impacts
- 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

Foods consumable by humans

- Land
- Water

Foods not consumable by humans

- Wastes
- Heat energy

Non-food usable energy sources, fertilizers, and other chemicals

Human-consumable milk and beef

This is too complicated to use!
Feed efficiency on the farm

Feed

- Lactating cows
- Dry cows
- Heifers

Wasted feed

- Feces
- Urine
- Gas
- Heat

Milk
Calves
Body tissue
**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
2. Increase milk production relative to maintenance.
Is there an optimal milk production and body size?

Feb 15, 2010: Wisconsin cow Ever-Green-View My 1326-ET became the national milk production record holder, at 4 yr 5 mo. of age. She produced a 365-day record of 72,200 lbs of milk, with 2,790 lbs of fat and 2,140 lbs of protein.

If a cow produces this much, I don’t care if she weighs 2000 lb!
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.
High production per unit BW means greater efficiency, but the returns in efficiency from more milk are diminishing.
The dilution of maintenance: milk vs cow size

Whether we get more milk with the same BW or the same milk with a smaller BW, the cow is operating at a higher level and efficiency increases (but maybe not much).

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Graph: The graph shows the relationship between intake relative to body weight and milk energy intake. The x-axis represents the intake relative to body weight, ranging from 1 to 5. The y-axis represents the milk energy intake as a percentage of GE intake, ranging from 0% to 40%. The graph includes two lines: one for increasing milk with the same BW and another for decreasing BW with the same milk. The increase in milk with the same BW shows a higher percentage of milk energy intake at all levels of intake relative to body weight compared to decreasing BW with the same milk.
Should we select for smaller cows?

Assumption for last 60 years was that
NEL requirement for maintenance
= 0.08 x BW^{0.75}
Body Weight Trend in U.S. Holsteins

+2.3 kg/year from 1970 to present

Potts et al., 2017
Maintenance requirement – what is it?

- NRC 2001: 0.08 x Metabolic BW
- Birnie et al., 2000: 0.084 to 0.113 x MBW depending on BCS
- Moraes et al., 2015: 0.086 to 0.115 x MBW depending on decade
- Tempelman et al., 2015: 0.11 to 0.17 x MBW depending on research farm

*If the maintenance requirement increases, then the optimal level of milk production relative to body weight to achieve maximal feed efficiency will also increase.*
Genetic (upper right) and non-genetic (lower left) correlations and heritabilities (diagonal) for efficiency traits on 5700 Holsteins. Lu et al., unpublished.

<table>
<thead>
<tr>
<th></th>
<th>MilkE</th>
<th>MBW</th>
<th>DMI</th>
<th>Gross Eff.</th>
<th>IOFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>MilkE</td>
<td>0.37 ± 0.03</td>
<td>0.06 ± 0.06</td>
<td>0.66 ± 0.04</td>
<td>0.66 ± 0.08</td>
<td>0.97 ± 0.01</td>
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<td>MBW</td>
<td>0.22 ± 0.04</td>
<td>0.51 ± 0.03</td>
<td>0.45 ± 0.05</td>
<td>-0.28 ± 0.06</td>
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<td>DMI</td>
<td>0.56 ± 0.02</td>
<td>0.37 ± 0.03</td>
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<td>-0.11 ± 0.04</td>
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<td>Gross Eff.</td>
<td>0.39 ± 0.02</td>
<td>-0.03 ± 0.01</td>
<td>-0.19 ± 0.02</td>
<td>0.13 ± 0.00</td>
<td>0.70 ± 0.05</td>
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<td>IOFC</td>
<td>0.85 ± 0.01</td>
<td>0.17 ± 0.04</td>
<td>0.34 ± 0.03</td>
<td>0.77 ± 0.01</td>
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</table>

Selection against body size will enhance feed efficiency but not milk income per cow. Selection for milk increases both.
**Summary for body size and efficiency**

Liu et al., 2015. Body weight.

- For 5700 Holsteins, body weight was not genetically correlated with milk energy per day. The genetic correlation of body weight with gross feed efficiency was -0.3.

Manzanilla-Pech et al., 2015. Stature.

- For 1900 US Holsteins, stature was not genetically correlated with milk energy/day. The genetic correlation of stature with gross feed efficiency was -0.7 and with residual feed intake was +0.4.

- Selecting for bigger, taller cows does not increase milk.
- Selecting for bigger, taller cows decreases feed efficiency.
Other considerations in the size debate

- Milk yield is more important than body size.
- Feed efficiency must be considered on a whole-farm basis.
- Smaller cows need less space so get more cows per farm.
- Smaller cows take about as much time to manage per head.
- Smaller cows and their bull calves have less salvage value.
- Smaller cows might have fewer health problems.
- Smaller cows might handle heat stress better.
- Smaller cows might be better in a grazing system.
- Smaller cows might need more digestible diets.
- Height might be more important than weight.
Two main components of feed efficiency

1. Efficient cows produce a lot of milk for their size!

2. Efficient cows efficiently convert feed to net energy—they likely eat a lot but the feed is used for milk.
We want more than just efficiency

Our goal is a cow that efficiently converts feed to milk
– has high GE to NE (low RFI) because of greater digestibility, greater % of DE to NE, or lower maintenance
– efficiently captures (partitions) lifetime NE to product because she operates at a high multiple of maintenance
– is profitable (high production dilutes out farm fixed costs)
– has minimal negative environmental impacts

AND
• is healthy and thrives through the transition period
• yields products of high quality and salability
• is fertile and produces high-value offspring
• is adaptable to different climates and diets
• can use human-inedible foods, pasture, and cheap feeds
• can digest feeds better
• requires less protein and phosphorus per unit of milk
• has a good disposition and looks happy to the general public
Conclusions of USDA Study

• Stature and body weight are negatively correlated with Gross Feed Efficiency at $r = -0.7$ and -0.3.

• Residual feed intake (RFI) is moderately heritable at ~0.17.

• 61,000 SNP markers accounted for 14% of the variance in RFI. Top ten SNP accounted for 7% of the variance.

• The range in sire breeding values for RFI is ~900 lb of feed DM per lactation. The range in DMI due to BW variation and RFI in combination is ~1400 lb/lactation.

• Residual feed intake could get ~16% of relative emphasis in net merit, but low REL for young animals will limit progress.
<table>
<thead>
<tr>
<th>Institution</th>
<th># cows</th>
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<td>Other</td>
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<td>345</td>
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</tr>
<tr>
<td>U Alberta</td>
<td>288</td>
<td>516</td>
<td>261</td>
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<td><strong>TOTAL</strong></td>
<td><strong>5863</strong></td>
<td><strong>7655</strong></td>
<td><strong>5207</strong></td>
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</table>

European collaborators 3600 1900
Improving dairy feed efficiency, sustainability, and profitability by impacting breeding and culling decisions.

$2 million for 2019 - 2024
<table>
<thead>
<tr>
<th>Institution</th>
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<tbody>
<tr>
<td>Michigan State</td>
<td>Rob Tempelman</td>
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<tr>
<td>U Wisconsin</td>
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<td>Heather White</td>
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<tr>
<td>Iowa State</td>
<td>James Koltes</td>
<td>Hugo Ramirez-Ramirez</td>
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<tr>
<td>U Florida</td>
<td>Francisco Peñagaricano</td>
<td>Jose Santos</td>
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<td>USDA AGIL</td>
<td>Paul Van Raden</td>
<td>Randy Baldwin</td>
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<tr>
<td>CDCB</td>
<td>Joao Durr</td>
<td>Kristen Parker-Gaddis</td>
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<td>Javier Burchard</td>
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Overview of Project Aims

Aim 1: 3600 new DMI phenotypes

More cows with high impact genetics on research farms

Aim 2: Sensor and milk spectra data on >3000 cows

Better GEBV for feed efficiency and inclusion in Net Merit

Aim 3: Long-term strategic planning

Long-term increases in feed efficiency and profitability

Aim 4: Estimates for methane emissions on >300 cows

Long-term increases in US dairy farm sustainability