Feed Efficiency, RFI and the Benefits for the Beef Industry

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Feed Efficiency in Beef Cattle: Why?

56-71% of total cost of production for cow-calf operations is associated with feed, bedding and pasture
(Alberta Agriculture and Rural Development 2005)

65-75% of the total dietary energy cost in breeding cows is required for maintenance (Ferrell & Jenkins 1985; NRC 1996)

Genetic improvement in feed efficiency - estimated: $50-100 million annually to Alberta’s beef cattle industry
Energetic Efficiency in growing beef cattle

1. Feed Intake

2. Feed Conversion Ratio: DMI/ADG;
   CV for DMI, 8-12%; CV for ADG, 16-20%

3. Partial Efficiency of growth: ADG/(avg. DMI-expected DMI_m)
   efficiency of growth after removing FI for maintenance

4. Relative Growth Rate: 100 x [log end wt – log start wt]/days on test
   Growth relative to instantaneous body size

5. Kleiber Ratio: ADG/avg test period LWT ^ 0.75
   weight gain per unit of metabolic body weight

All measures are related to body size, growth and composition of gain
Maintenance requirements of beef cattle is largely unchanged over last 100 years (Johnson, Ferrell and Jenkins, 2003)

**Figure 1.** Average EPD (Mcal/yr) for mature cow maintenance energy requirements by birth year in Red Angus cattle (Evans et al., 2002).
% Change in greenhouse gas emissions and global warning potential achieved through genetic improvement (1988-2007)

<table>
<thead>
<tr>
<th></th>
<th>CH$_4$</th>
<th>NH$_3$</th>
<th>N$_2$O</th>
<th>GWP$_{100}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickens – layers</td>
<td>-30</td>
<td>-36</td>
<td>-29</td>
<td>-25</td>
</tr>
<tr>
<td>Chickens – broilers</td>
<td>-20</td>
<td>10</td>
<td>-23</td>
<td>-23</td>
</tr>
<tr>
<td>Pigs</td>
<td>-17</td>
<td>-18</td>
<td>-14</td>
<td>-15</td>
</tr>
<tr>
<td>Cattle – dairy</td>
<td>-25</td>
<td>-17</td>
<td>-30</td>
<td>-16</td>
</tr>
<tr>
<td>Cattle – beef</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sheep</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>-1</td>
</tr>
</tbody>
</table>


Pork 2.8-4.5 kg CO$_2$e/kg pork; chicken 1.9-2.9 kg CO$_2$e/kg chicken; Dairy 1.3 kg CO$_2$e/kg milk

**Beef 18-36 kg CO$_2$e/kg beef**
Variation in the carbon footprint per kilogram of beef by region and beef production system (Basarab et al. 2012; Capper 2011)
Figure 1. Breakdown of total greenhouse gas (GHG) emissions resulting from hormone free and growth implanted calf-fed and yearling-fed beef production systems (CO$_2$ equivalents, 160 cow-herd assumed).

**Calf-fed, Hormone Free**
Animal GHG emissions = 922,107 kg CO$_2$ e

- Feeder 14.5%
- Replacement bulls 1.3%
- Spring culled cows 3.9%
- Fall culled cows 3.2%
- Replacement heifers 3.4%
- Herd bulls 3.6%

**Yearling-fed, Hormone Free**
Animal GHG emissions = 1,219,659 kg CO$_2$ e

- Feeder 35.4%
- Replacement bulls 1.0%
- Spring culled cows 3.0%
- Fall culled cows 2.4%
- Replacement heifers 2.6%
- Herd bulls 2.7%

**Calf-fed, Growth Implanted**
Animal GHG emissions = 928,344 kg CO$_2$ e

- Feeder 15.1%
- Replacement bulls 1.3%
- Spring culled cows 3.9%
- Fall culled cows 3.1%
- Replacement heifers 3.4%
- Herd bulls 3.5%

**Yearling-fed, Growth Implanted**
Animal GHG emissions = 1,237,082 kg CO$_2$ e

- Feeder 36.3%
- Replacement bulls 1.0%
- Spring culled cows 2.9%
- Fall culled cows 2.4%
- Replacement heifers 2.5%
- Herd bulls 2.7%

Total GHG emissions include methane from enteric fermentation and manure, nitrous oxide from manure, carbon dioxide from energy use and nitrous oxide from cropping.
Energetic Efficiency in growing beef cattle

Residual Feed Intake (RFI) also called Net Feed Efficiency:

FEED INTAKE ADJUSTED FOR BODY SIZE AND PRODUCTION - growing cattle is the difference between an animal's actual feed intake & its expected feed requirement for maintenance of body weight, growth and changes in fatness.

- moderately heritable ($h^2 = 0.29-0.46$)
- reflects an animal’s energy requirement for maintenance.

![Graph showing RFI distribution and calculated costs](image-url)

Olds College; 96 British bulls (2003-05)
Cost difference: -RFI vs. +RFI
3.0 kg as fed/day x $0.15/kg x 140 days = $63
Diet (as fed basis): 76% barley silage; 30% barley grain & 3% beef sup. (32 % CP)
Selection for low RFI will:

1. Have no effect on growth & animal size

Phenotypic ($r_p$) & genetic correlations ($r_g$) are near zero

Arthur et al. 2001; Basarab et al. 2003; Crews et al. 2003; Jensen et al. 1992

148 steers from 5 genetic strains fed a finishing diet and gaining 1.52 kg/day. No relationship to slaughter weight, hip height and gain in hip height (Basarab et al. 2003).
2. Reduce feed intake by 10-12% at equal body size & ADG

$rp = 0.60-0.72; \ rg = 0.69-0.79$ (Arthur et al. 2001; Basarab et al. 2003, 2007, 2011; Herd et al. 2002)

73 hybrid bulls
Olds College,
Fall 2006
$rp = 0.64$
3. Improve Feed Conversion Ratio (FCR) by 9-15% at equal body size & average daily gain

rp=0.53-0.70; rg = 0.66-0.88; Arthur et al. 2001; Basarab et al. 2003, Herd et al. 2002

148 steers
rp = 0.43
Lacombe
4. No effect on carcass fat provided RFI is adjusted for fatness (Basarab et al. 2003; Nkrumah et al. 2007)

Phenotypic ($r_p$) & genetic correlations ($r_g$) are inconsistent & near zero (0.20 to –0.20)

**Classical Serial Slaughter Study:**
Total whole body composition (water, fat, protein, ash & energy); MEI = Retained energy + Heat Production

Liver weight: 7.8% ↓ LOW RFI (P=0.007)
Stomach complex: 7.6% ↓ LOW RFI (P=0.004)
Heat production: 9.3% ↓ LOW RFI (P<0.001)
5. Lower heat production by 9-10%
(MEI=RE+HP; HP=NEm + HIF)

*Basarab et al. 2003; Nkumah et al. 2007*
6. Lower methane emissions by 15-30% & manure production by 15-20%

Okine et al. 2001; Arthur et al. 2002; Nkrumah et al. 2007; Hegarty et al. 2007
Comparative Greenhouse Gas emissions from selecting for low RFI (EBV of 0 vs. -0.5 kg DM/day) in beef cattle

GHG emissions of 4 bulls, slaughter steers & slaughter heifers and replacement heifers; 3 years from bull purchase

Baseline  EBV=0.0, 372.6 t CO2e
Project    EBV=-0.5, 348.3 t CO2e

$ 243 CAN @ $10/t CO2e  
$2150 CAN in feed savings
Three Cross Ranch – 2007 breeding season

Mating Grp 1
+RFI -RFI
X 123 cows

Mating Grp 2
+RFI -RFI
X 121 cows

Mating Grp 3
+RFI -RFI
X 48 cows

Morison’s Feedlot – Jun – Sep 2009 Feed Intake test, 240 feeders
(barley silage:grain (60:40%) diet) 

n=73, mean=0.00 
SD= 0.506 
R^2 x 100 = 58.2%
## 7. No effect on bull fertility

*Wang, Ambrose, Colazo, Basarab et al., J. Anim. Sci. 2011*

Relationship ($r_p$) between RFI and breeding soundness in yearling beef bulls

<table>
<thead>
<tr>
<th>Traits</th>
<th>n</th>
<th>$r_p$</th>
<th>sign.</th>
</tr>
</thead>
<tbody>
<tr>
<td>365-day SC, cm</td>
<td>404</td>
<td>0.01</td>
<td>NS</td>
</tr>
<tr>
<td>Front feet score</td>
<td>343</td>
<td>0.02</td>
<td>NS</td>
</tr>
<tr>
<td>Front leg score</td>
<td>274</td>
<td>-0.01</td>
<td>NS</td>
</tr>
<tr>
<td>Hind feet score</td>
<td>343</td>
<td>0.03</td>
<td>NS</td>
</tr>
<tr>
<td>Disposition score</td>
<td>343</td>
<td>-0.04</td>
<td>NS</td>
</tr>
<tr>
<td>Semen morphology</td>
<td>260</td>
<td>0.08</td>
<td>NS</td>
</tr>
<tr>
<td>Semen motility</td>
<td>260</td>
<td>0.14</td>
<td>*</td>
</tr>
<tr>
<td>Semen conc. score</td>
<td>260</td>
<td>-0.09</td>
<td>NS</td>
</tr>
<tr>
<td>Progeny produced (27 sires)</td>
<td>0.00</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

No difference in culling reasons: 42.1% of +RFI & 41.5% -RFI bulls culled
3.7% reduction in DMI (0.35 kg DM/d/9.5 kg DM/d); cow 13 kg DM/d x 3.7% x $0.15/kg DM x 365 = $26/cow

Sire phenotypic RFI, kg DM/day

Average Progeny RFI, kg DM/day

\[ y = 0.016 + 0.352x, \]
\[ \text{sire}=13, R^2 = 57.3\% \]

0.352 kg DM/day x $0.30/kg DM x 150 days

= $15.84/hd

Relationship between sire phenotypic RFI and average progeny phenotypic RFI (Three Cross Ranch)

Where r-square for growth curves was greater than 0.95 and progeny per sire is 2 or more.
Slope equal for slaughter heifers and steers.

3.7% reduction in DMI (0.35 kg DM/d/9.5 kg DM/d); cow 13 kg DM/d x 3.7% x $0.15/kg DM x 365 = $26/cow
Effect of sire RFI on the carcass quality of their progeny

<table>
<thead>
<tr>
<th>Progeny performance</th>
<th>Sires</th>
<th>Sires</th>
<th>Sign.</th>
</tr>
</thead>
<tbody>
<tr>
<td>During finishing</td>
<td>+RFI</td>
<td>-RFI</td>
<td></td>
</tr>
<tr>
<td>Number of progeny</td>
<td>95</td>
<td>144</td>
<td></td>
</tr>
<tr>
<td>Progeny carcass weight, kg</td>
<td>366</td>
<td>372</td>
<td>NS</td>
</tr>
<tr>
<td>Progeny carcass grade fat, mm</td>
<td>11.0</td>
<td>11.3</td>
<td>NS</td>
</tr>
<tr>
<td>Progeny ribeye area, cm²</td>
<td>93.5</td>
<td>93.7</td>
<td>NS</td>
</tr>
<tr>
<td>Progeny marbling score</td>
<td>4.22</td>
<td>4.30</td>
<td>NS</td>
</tr>
<tr>
<td>Progeny yield grade</td>
<td>1.38</td>
<td>1.45</td>
<td>NS</td>
</tr>
<tr>
<td>Progeny lean meat yield, %</td>
<td>58.6</td>
<td>58.4</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS, not significant, P>0.05
Individual Animal Feed Intake Facility, Lacombe Research Centre, AB, Canada
Cow productivity & reproductive fitness

56.6% barley straw: 40.0% silage
3.4% Feedlot sup (32% CP)
ad libitum twice daily

30% straw: 70% grass hay (DM basis)
9.6% CP, 8.75 MJ ME/kg DM
8. No effect of RFI\textsubscript{fat} on age at puberty and pregnancy

A. Levels of significance are given for cumulative percent of heifers reaching puberty by 9, 10, 11, 12, 13, 14 and 15 mo of age. B. Levels of significance are given for cumulative percent heifers pregnant by 2, 7, 12, 17, 22, 27, 32 and 37 d of the breeding season. Adapted from Basarab et al. (2011).
9. No effect of calving pattern

RFI adj. for fat

n = 75  n = 73

NS  NS  NS  NS  NS
### Productivity traits in -RFI and +RFI first calf heifers

<table>
<thead>
<tr>
<th>Trait</th>
<th>Heifer RFI</th>
<th>fat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-RFI</td>
<td>+RFI</td>
</tr>
<tr>
<td>Heifers exposed to breeding</td>
<td>98</td>
<td>92</td>
</tr>
<tr>
<td>Calving difficulty, %</td>
<td>6.7</td>
<td>9.2</td>
</tr>
<tr>
<td>Total calf death, %</td>
<td>5.3</td>
<td>11.8</td>
</tr>
<tr>
<td>Calf death unknown, %</td>
<td>2.7</td>
<td>7.9</td>
</tr>
<tr>
<td>Weaning rate, %</td>
<td>71.4</td>
<td>71.7</td>
</tr>
<tr>
<td>Birth weight, kg</td>
<td>36.6</td>
<td>36.5</td>
</tr>
<tr>
<td>Pre-weaning ADG, kg/day</td>
<td>0.98</td>
<td>0.99</td>
</tr>
<tr>
<td>Weaning weight, kg</td>
<td>251</td>
<td>255</td>
</tr>
<tr>
<td>Heifer productivity, kg/hd/yr</td>
<td>186</td>
<td>191</td>
</tr>
</tbody>
</table>

Basarab et al. 2011; improved early life survival 1) better uterine env. due to more available nutrients, and 2) lower reactive oxygen species, proton leakage in mitochondria and oxidative stress at cell level.
LOW RFI cow J1042 (5 yr-old Hereford-Angus cow in the spring of 2004; RFI adj = -2.64 kg as fed/day; 2003 weight at weaning = 787 kg).

HIGH RFI cow E1245 (8 yr-old Hereford-Angus cow in the spring of 2004; RFI adj = 2.83 kg as fed/day; 2003 weight at weaning = 755 kg).

Note: cow RFI was adjusted for conceptus weight

10. No effect on pregnancy, calving or weaning rates. No effect on kg calf weaned/cow exposed to breeding (Arthur et al. 2005; Basarab et al. 2007)
Long-term (1997 to 2006) ultrasound back fat thickness of cows that produced -RFI and +RFI progeny

- Progeny RFI <=-0.44  • Progeny RFI >=0.44

- Progeny RFI <= -0.44
- Progeny RFI >= 0.44

Months from January 1, 1997
Relationship between $\text{RFI}_{\text{fat}}$ as a heifer and subsequent changes in body weight as a cow

- Begin swath grazing at ~3.5-yr old
- Reduces winter feeding costs by 47%

![Swath Grazing](image)
Relationship between $\text{RFI}_{\text{fat}}$ as a heifer and subsequent changes in body weight as a cow

- Backfat, 4.5 vs. 7.4 at 59 mo
- Backfat, 10.0 vs. 12.0 at 68 mo
- Begin swath grazing at ~3.5-yr old
# Repeatability of RFI in heifers to cows

Peter Lawrence, 2012, University College Dublin, Ireland

## RFI measured as a heifer

<table>
<thead>
<tr>
<th>Traits</th>
<th>High</th>
<th>Med</th>
<th>Low</th>
<th>sign.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, kg/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 mo of age</td>
<td>6.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.60&lt;sup&gt;c&lt;/sup&gt;</td>
<td>***</td>
</tr>
<tr>
<td>24 mo of age</td>
<td>8.62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.12&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>7.68&lt;sup&gt;b&lt;/sup&gt;</td>
<td>*</td>
</tr>
<tr>
<td>36 mo of age</td>
<td>9.66</td>
<td>8.95</td>
<td>8.96</td>
<td>NS</td>
</tr>
</tbody>
</table>

RFI computed on post-weaned heifers offered grass silage *ad libitum* and 2 kg concentrate/hd/day, and grass silage *ad libitum* during 1st and 2nd parity.

**Feed savings:** 1 kg DM/cow/d x $0.15/kg DM x 365 = $55/cow/yr
Selection for low RFI-fat will:

- Have no effect on growth, body size or slaughter weight
- Reduce feed intake at equal weight and ADG
- Improve feed to gain ratio by 10-15%
- Reduce net energy required for maintenance
- Reduce methane production by 20-30%
- Have no effect on carcass yield & quality grade
Selection for low RFI-fat will:

- Little if any effect on age at puberty
- No effect on calving pattern in first calf heifers
- No negative effect on pregnancy, calving or weaning rate
- Positive effect on body fatness/weight particularly during stressful periods
- Reduce feed costs - $0.05-0.10/hd/d feeders, $19-38 mil.
  - $0.08-0.15/hd/d in cows; $54-110 mil.
- Effect on feed intake on pasture??
Multi-trait Selection indices

**Feedlot profitability Index (FPI):**
Increase genetic potential of market progeny for feedlot profit (Crews et al. 2003)

\[
FPI = 7.43 \text{ EBV}_{\text{RFI-fat}} + 37.38 \text{ EBV}_{\text{ADG}} - 0.12 \text{ EBV}_{\text{WT365}}
\]

RFI-fat = bull’s RFI adjusted for final off-test ultrasound backfat thickness, kg DMI/day

ADG = bull’s post-weaning average daily gain, kg/day

WT365 = bull’s 365-day weight, kg

Also consider carcass grade fat thickness, ribeye area and marbling
Multi-trait Selection indices

Maternal Productivity Index (MPI): consistently wean heavy calves over a sustained herd life, while controlling cow feed costs (Mwansa et al. 2002).

\[
\text{MPI} = 3.00 \text{EBV}_{\text{WWTd}} + 2.70 \text{EBV}_{\text{WWTm}} - 0.49 \text{EBV}_{\text{COWT}} + 2.39 \text{EBV}_{\text{SURV3}}
\]

\( \text{WWTd} = \text{direct weaning weight (30\%)} \)

\( \text{WWTm} = \text{maternal weaning weight (26\%)} \)

\( \text{COWT} = \text{cow weight (17\%)} \)

\( \text{SURV3} = \text{ability of a female to produce at least 3 calves given she became a dam (27\%)} \)

Also consider heifer/bull RFI-fat adjusted, age at first calving, calving ease and birth weight
Biological Mechanisms Contributing to Variation in RFI

Others (e.g. protein turnover, ion pumping, protein leakage, thermoregulation, stress (60%))

Feeding Patterns (2%)

Body composition (5%)

Heat Increment (9%)

Digestion (14%)

Activity (10%)

Richardson and Herd, 2004
Herd et al., 2004
Relationship of feedlot RFI with fecal DM, urine and methane production in steers fed at 2.5x NEm.

<table>
<thead>
<tr>
<th>Trait</th>
<th>HIGH RFI</th>
<th>LOW RFI</th>
<th>Sign. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFI, kg DM/day</td>
<td>1.25</td>
<td>-1.18</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Metabolic BW</td>
<td>89.0</td>
<td>93.8</td>
<td>0.48</td>
</tr>
<tr>
<td>ADG, kg/day</td>
<td>1.46</td>
<td>1.48</td>
<td>0.39</td>
</tr>
<tr>
<td>DMI, kg/day</td>
<td>11.62</td>
<td>9.62</td>
<td>0.01</td>
</tr>
<tr>
<td>Fecal DM, g/kg DMI</td>
<td>272</td>
<td>234</td>
<td>0.24</td>
</tr>
<tr>
<td>Urine, g/kg MWT</td>
<td>56.3</td>
<td>45.5</td>
<td>0.25</td>
</tr>
<tr>
<td>Urine N, g/kg DMI</td>
<td>8.60</td>
<td>7.13</td>
<td>0.19</td>
</tr>
<tr>
<td>CH₄, L/day</td>
<td>152.2</td>
<td>120.1</td>
<td>0.04</td>
</tr>
<tr>
<td>CH₄, % of GEI</td>
<td>4.28</td>
<td>3.19</td>
<td>0.04</td>
</tr>
</tbody>
</table>

LOW RFI: ME higher, HP lower, RE higher (kcal/kg MWT)
Feed intake tests favor later maturing heifers and bulls

**Cumulative Percentage of Heifers that Reached Puberty while being tested for feed intake (n=190)**

**Basarab et al. 2011, Dec. CJAS**

72.5% of heifers reached puberty by the end of test

Average Age at Puberty
351 d, SD=43

Pre-pubertal (109) consumed 4.7% less feed and 7.4% improved FCR (P<0.001) than post-pubertal (81) heifers given equal ADG, body size and backfat

Feed intake tests favor later maturing heifers and bulls


Estimated Breeding Value
A Simple Example

Individual RFI: -1.25 kg DM/d
Contemporary Group Average: 0.0 kg DM/d

Bull RFI-p EBV = -1.25 kg DM/day \times 0.40 = -0.5 kg DM/day
Cow RFI-p EBV = 0.00 kg DM/day \times 0.40 = 0.0 kg DM/day

Expected Progeny Difference =
\frac{(-0.5 + 0.0)}{0.5} = -0.25 kg DM/day
Relationship between heifer post-weaning RFI$_{fat}$ and their subsequent lifetime productivity

No difference in calf birth weight, pre-weaning ADG and weaning weight