Feed Efficiency, RFI and the Benefits for the Beef Industry

J.A. Basarab, P.Ag., Ph.D.

Alberta Agriculture and Rural Development
Lacombe Research Centre, Alberta, Canada

Tiffin Conference, Cattle Gate to Dinner Plate

19 January 2012, Lethbridge, Alberta

University of Alberta – Quaecumque Vera

Olds College

livestock gentec

ALMA – Alberta Livestock and Meat Agency Ltd.

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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. **<u>Feed Conversion Ratio: DMI/ADG;</u>**

   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)*

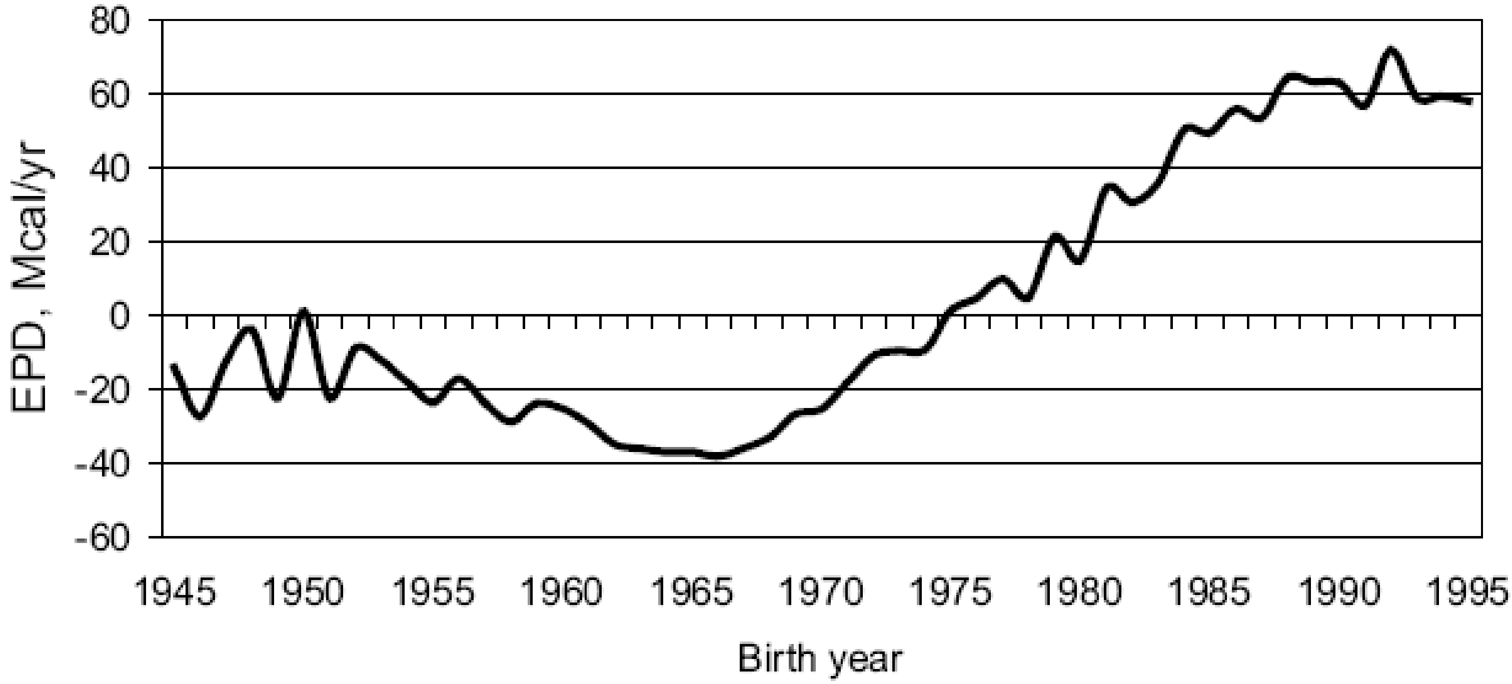


Figure 1. Average EPD (Mcal/yr) for mature cow maintenance energy requirements by birth year in Red Angus cattle (Evans et al., 2002).

% Change in greenhouse gas emissions and global warning potential achieved through genetic improvement (1988-2007)

	CH_4	NH_3	N_2O	GWP_{100}
Chickens – layers	-30	-36	-29	-25
Chickens – broilers	-20	10	-23	-23
Pigs	-17	-18	-14	-15
Cattle – dairy	-25	-17	-30	-16
Cattle – beef	0	0	0	0
Sheep	-1	0	0	-1

Sources: Project for DEFRA by Genesis Faraday Partnership and Cranfield University (AC0204) from Hume et al. (2011), J. Ag. Sci., doi:10.1017/S0021859610001188 .

Pork 2.8-4.5 kg CO_2e/kg pork; chicken 1.9-2.9 kg CO_2e/kg chicken; Dairy 1.3 kg CO_2e/kg milk

Beef 18-36 kg CO_2e/kg beef

Variation in the carbon footprint per kilogram of beef by region and beef production system (Basarab et al. 2012; Capper 2011)

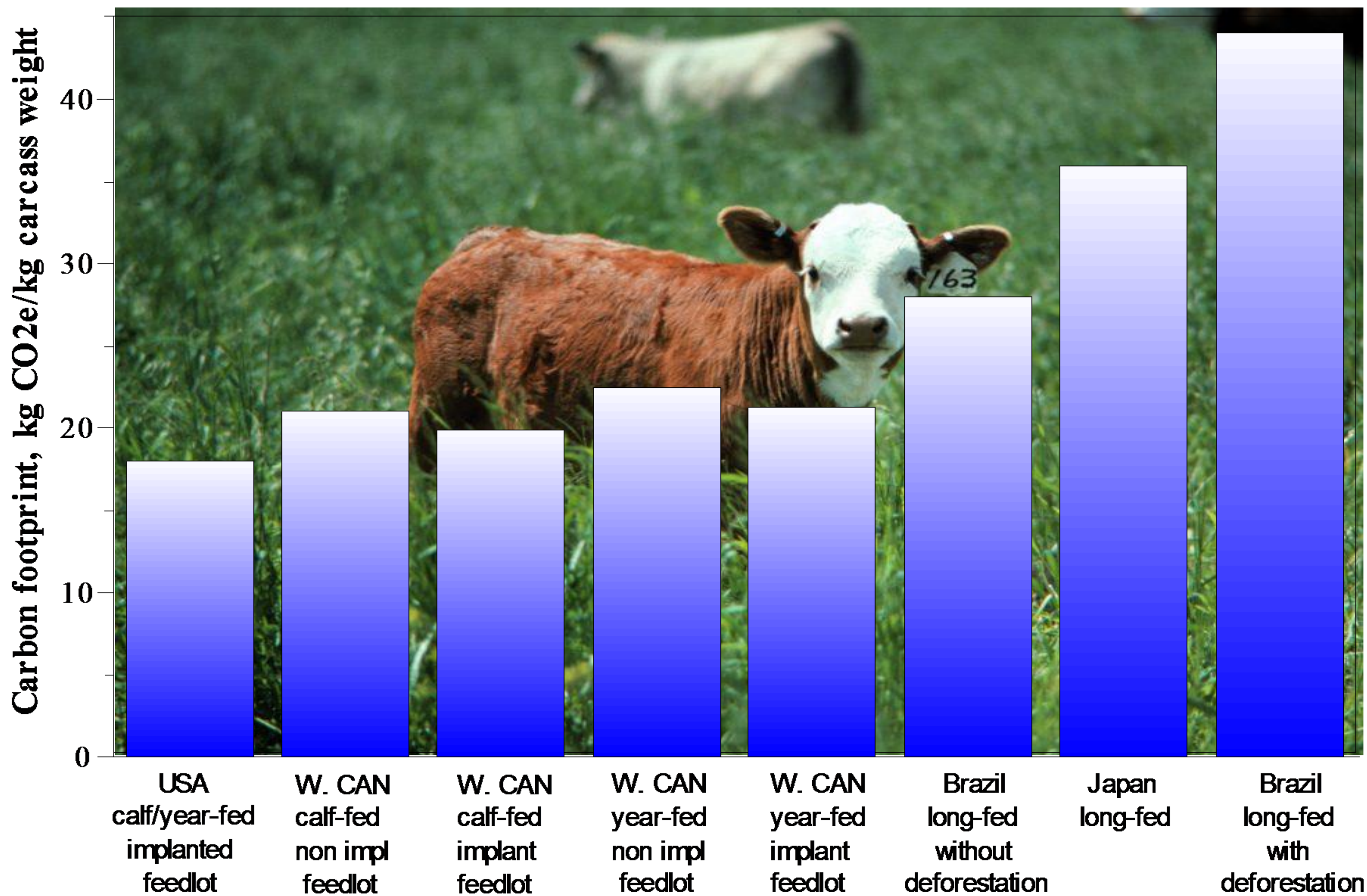
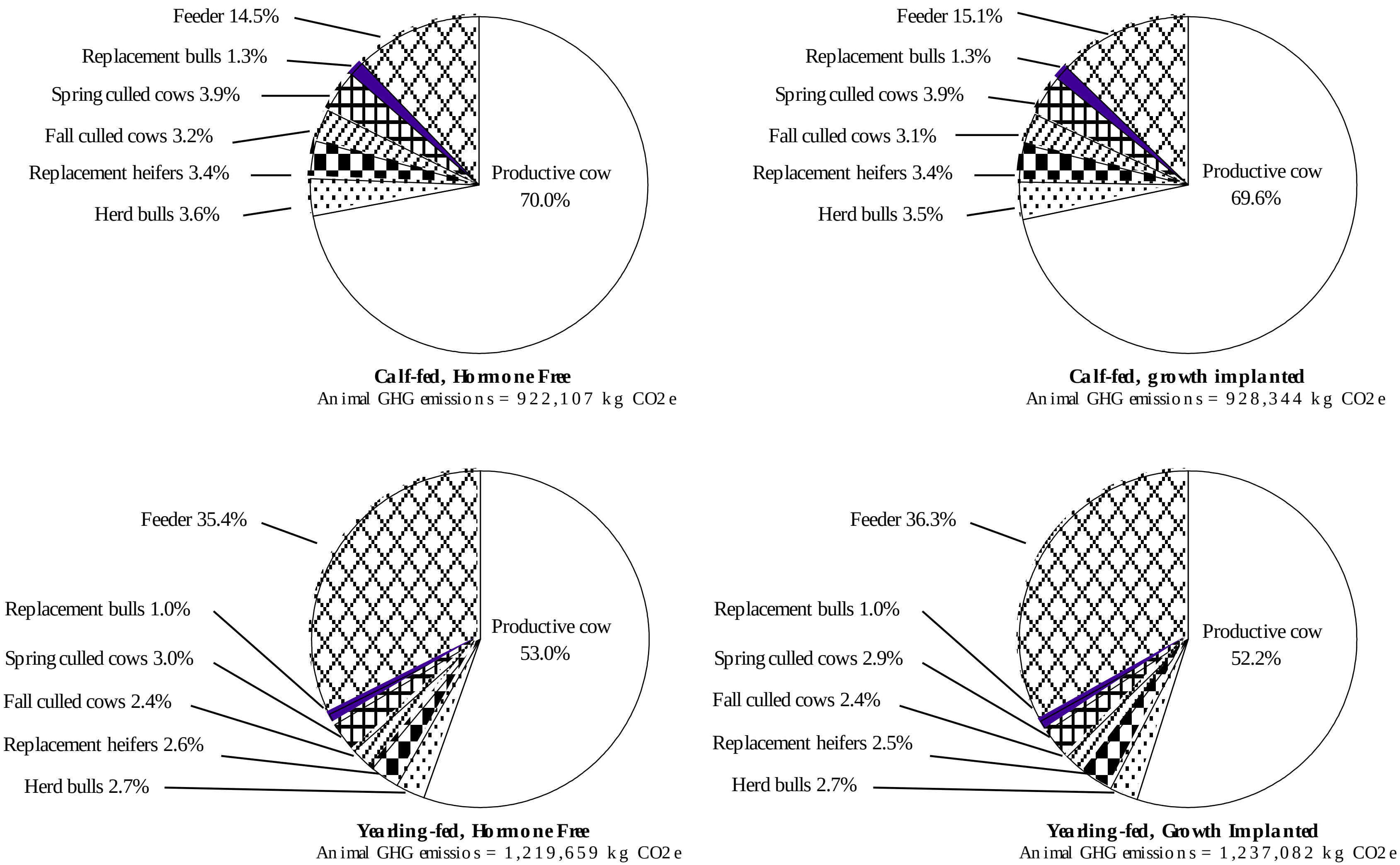


Figure 1. Breakdown of total greenhouse gas (GHG) emissions resulting from hormone free and growth implanted calf-fed and yearling-fed beef production systems (CO_2 equivalents, 160 cow-herd assumed).



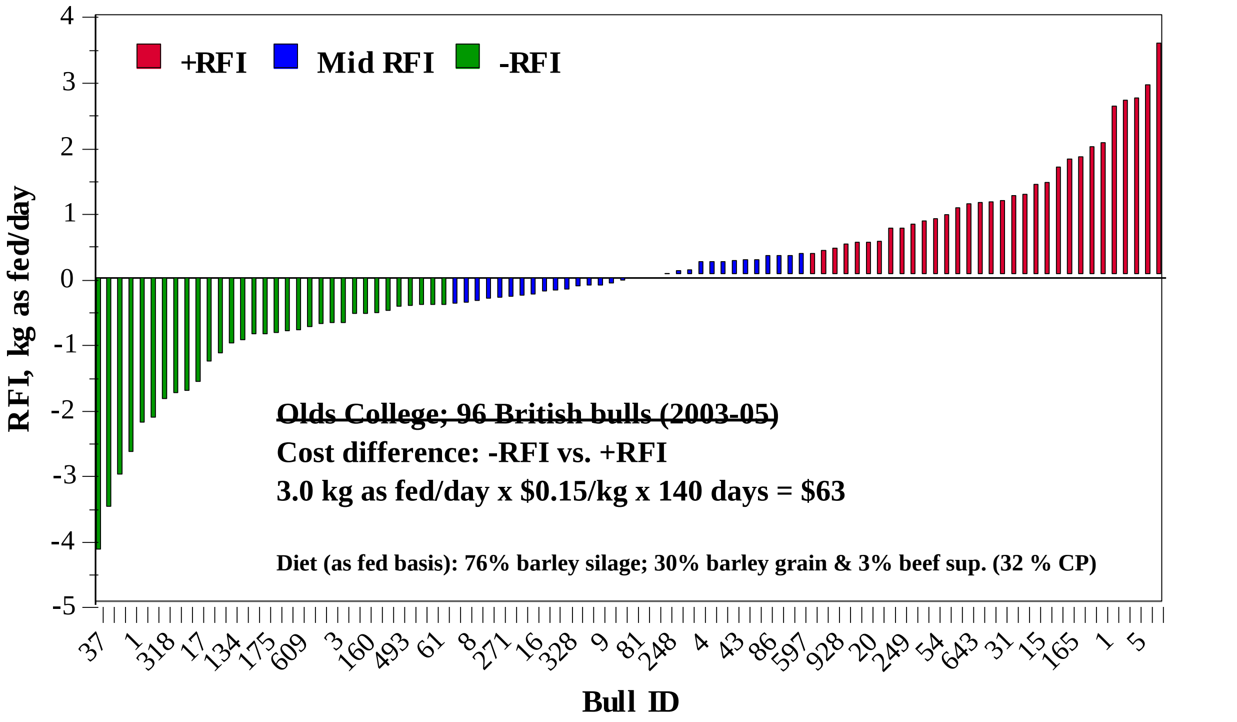
Total GHG emissions include methane from enteric fermentation and manure, nitrous oxide from manure, carbon dioxide from energy use and nitrous oxide from cropping.

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.**

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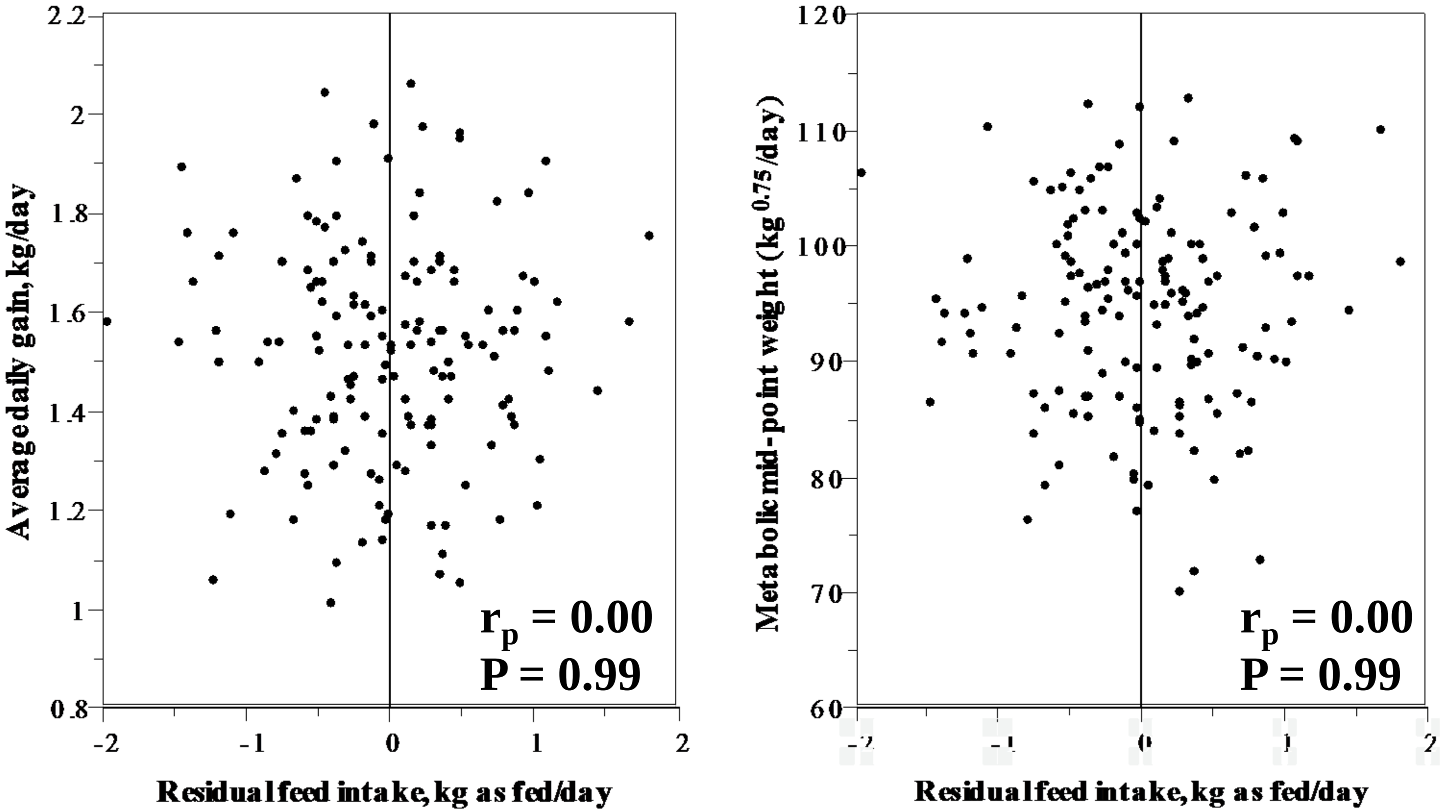
Selection for low RFI will:

1. Have no effect on growth & animal size

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

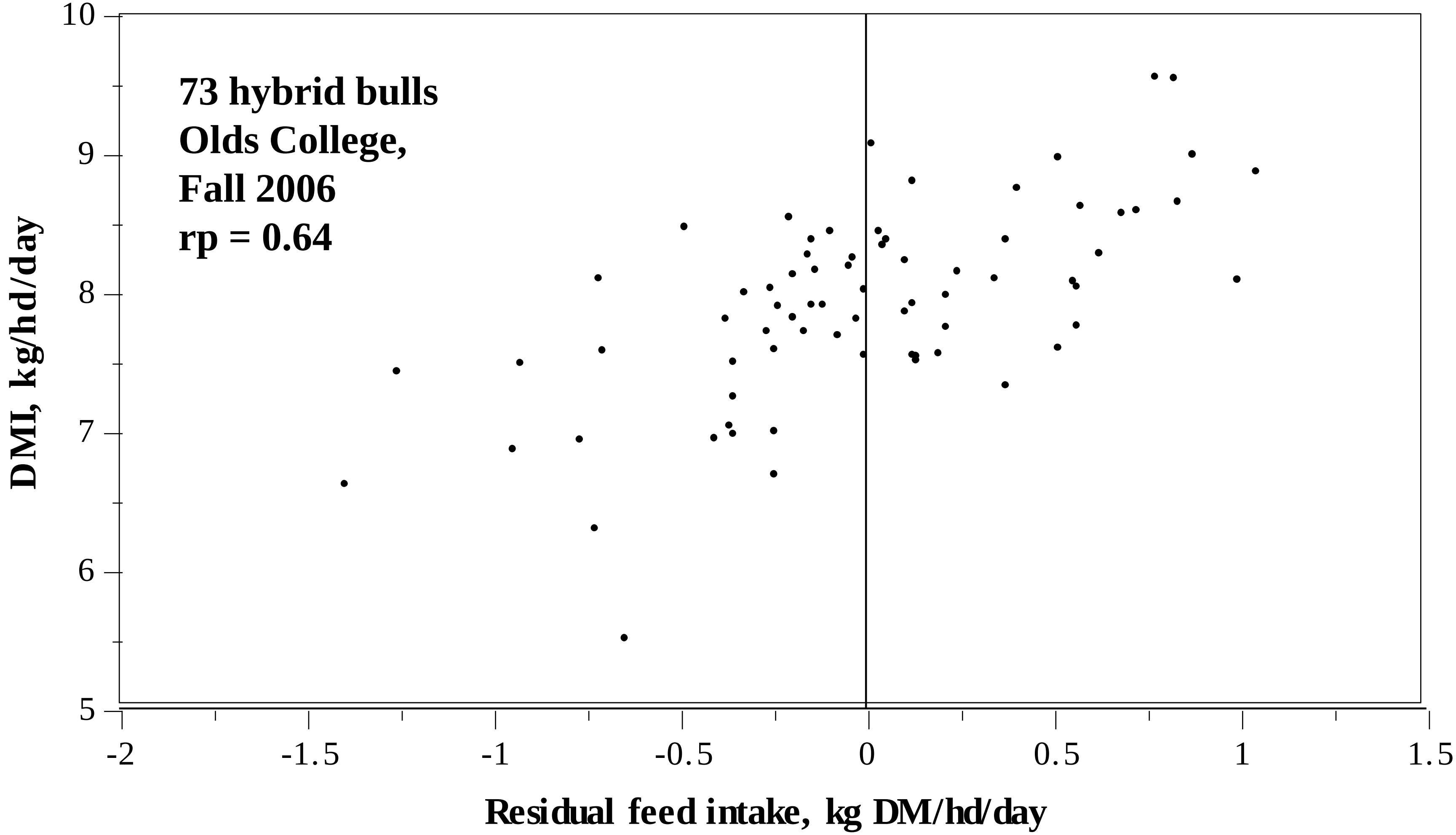
Arthur et al. 2001; Basarab et al. 2003; Crews et al. 2003; Jensen et al. 1992



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).

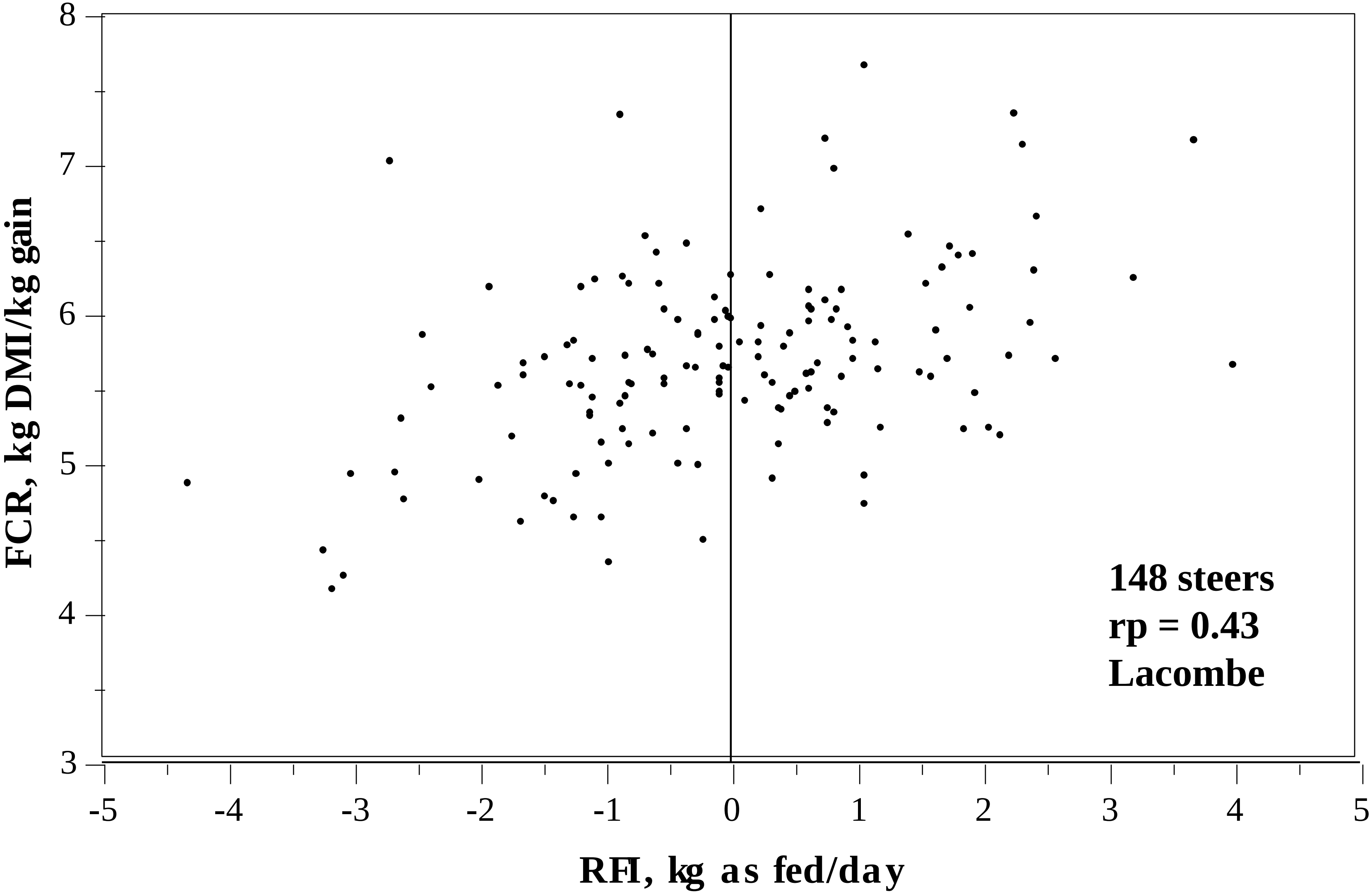
2. Reduce feed intake by 10-12% at equal body size & ADG

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



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***



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)

<u>Classical Serial Slaughter Study:</u>

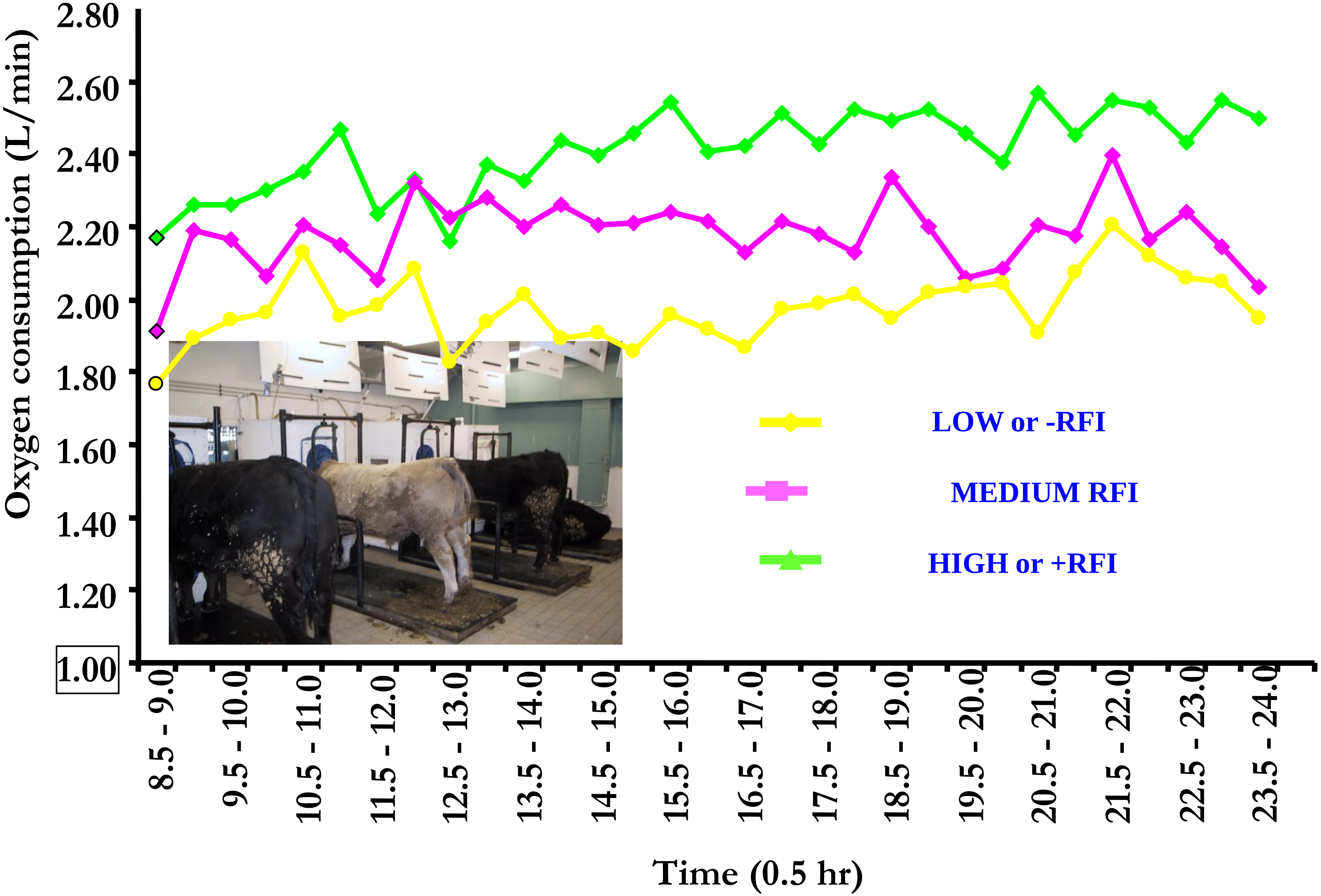
Total whole body composition (water, fat, protein, ash & energy); MEI = Retained energy + Heat Production

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%

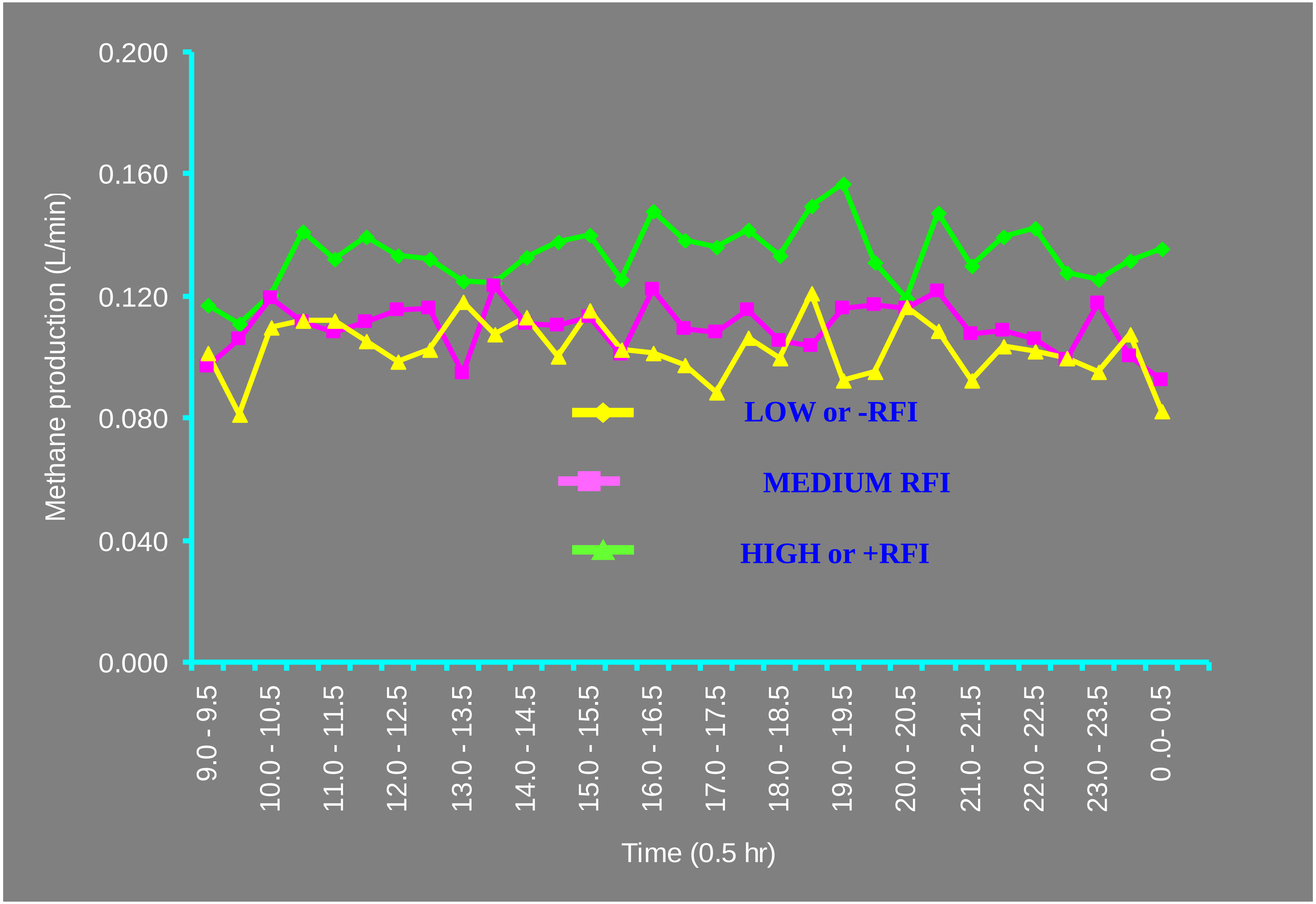
(MEI=RE+HP; HP=NEm + HIF)

Basarab et al. 2003; Nkrumah et al. 2007



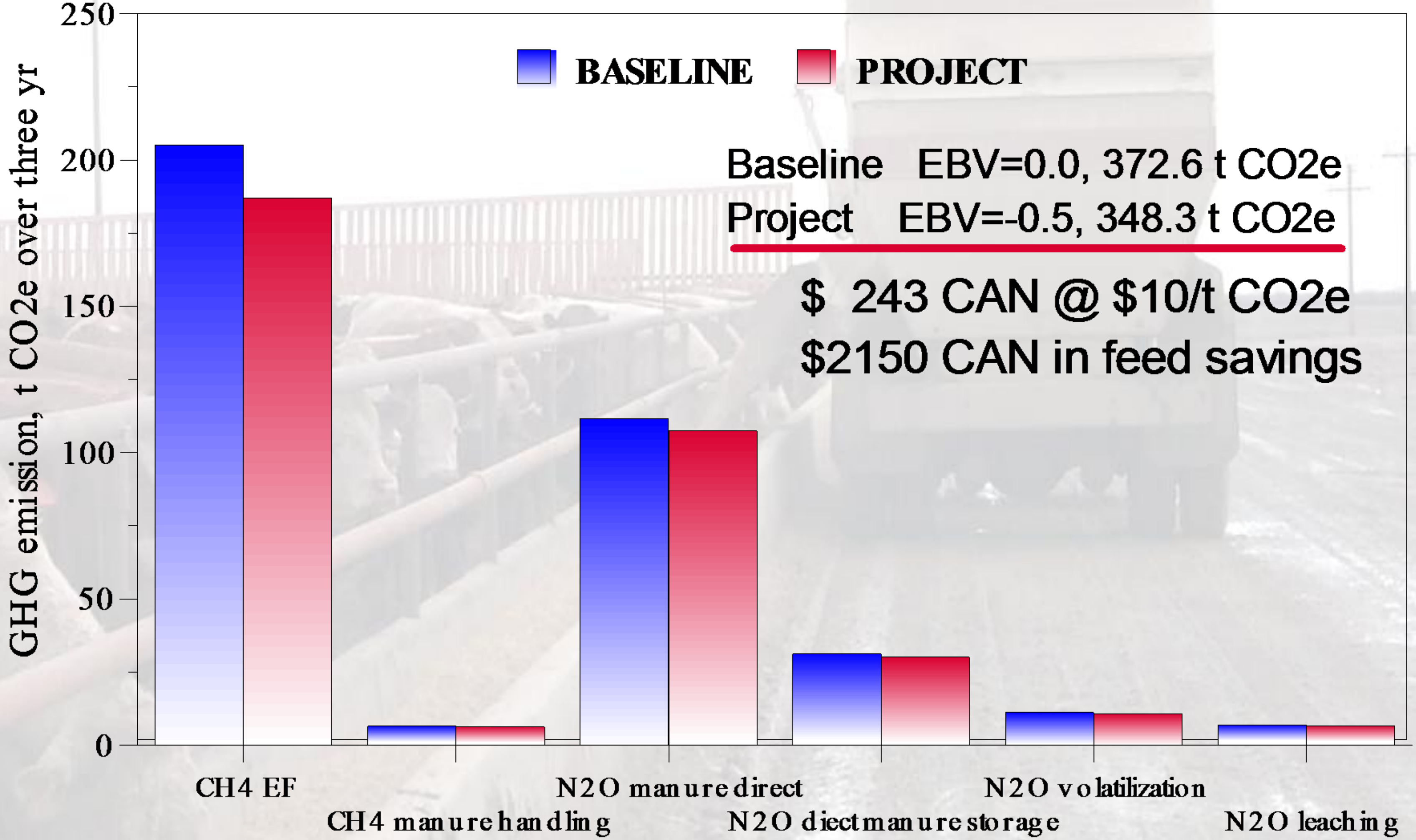
6. Lower methane emissions by 15-30% & manure production by 15-20%

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

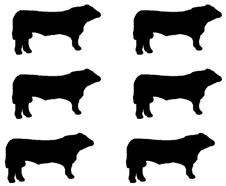
GHG emissions of 4 bulls, slaughter steers & slaughter heifers and replacement heifers; 3 years from bull purchase



Three Cross Ranch – 2007 breeding season

Mating Grp 1

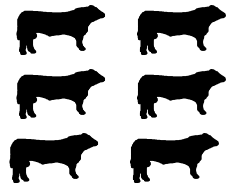
+RFI -RFI



X 123 cows

Mating Grp 2

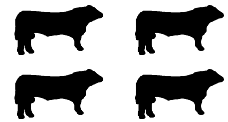
+RFI -RFI



X 121 cows

Mating Grp 3

+RFI -RFI

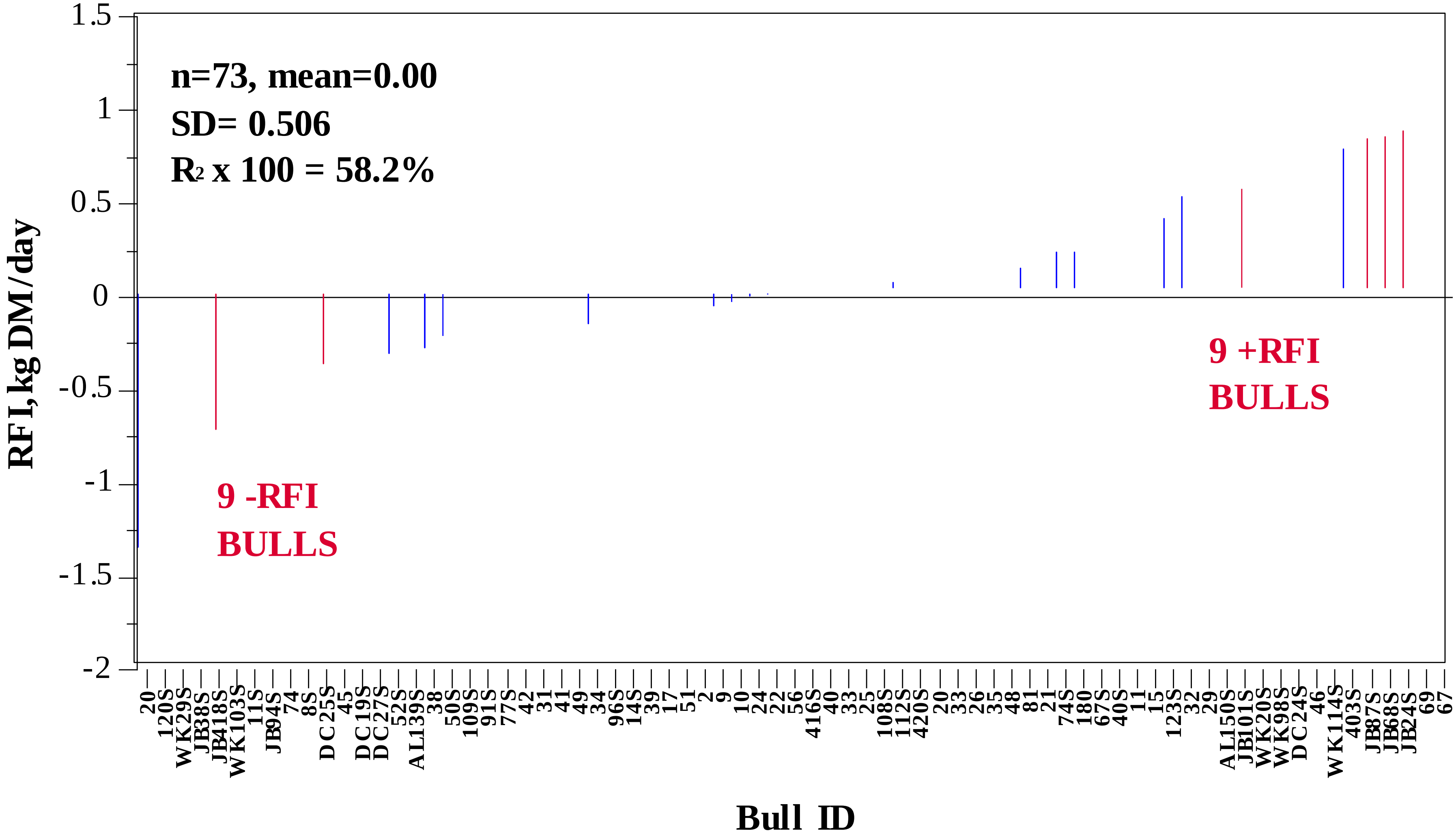


X 48 cows

Morison's Feedlot – Jun – Sep 2009 Feed Intake test, 240 feeders

Distribution of Residual Feed Intake (RFI) for TX BeefBooster bulls tested from Dec 11/2006 to Mar 8/2007.

(barley silage:grain (60:40%) diet)



7. No effect on bull fertility

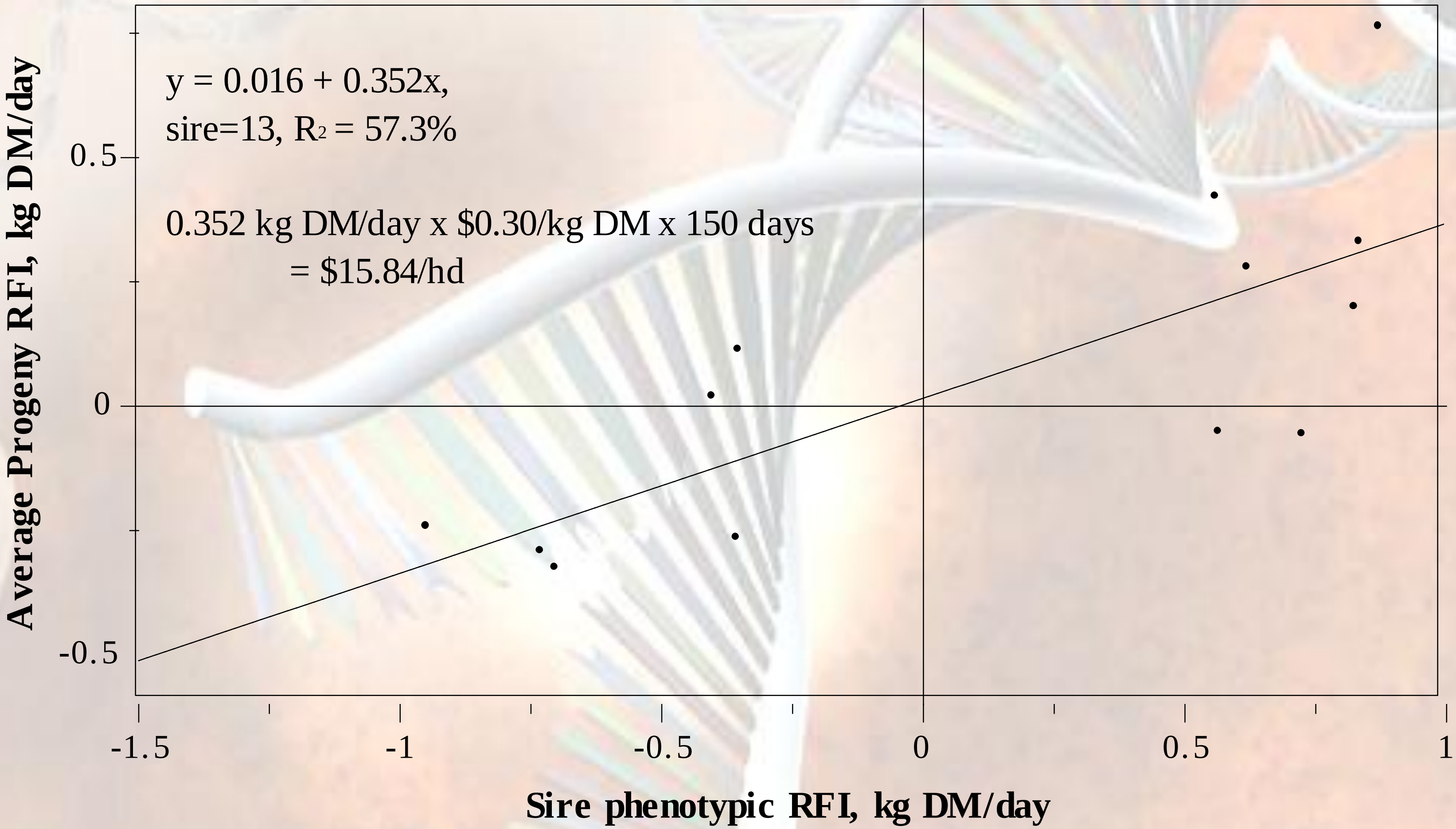
Wang, Ambrose, Colazo, Basarab et al., J. Anim. Sci. 2011

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

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

No difference in culling reasons: 42.1% of +RFI & 41.5% -RFI bulls culled

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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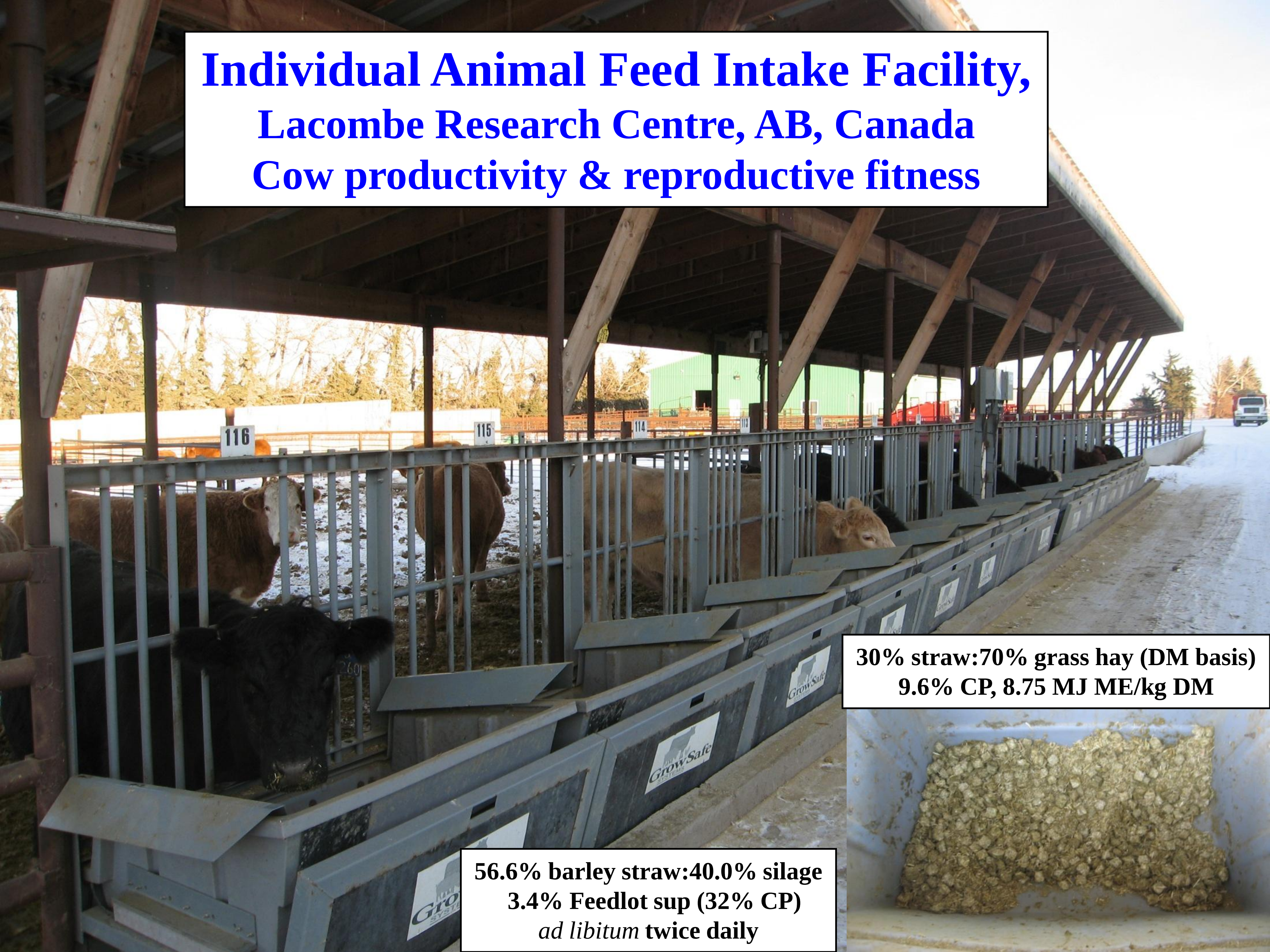
Effect of sire RFI on the carcass quality of their progeny

Progeny performance During finishing	**Sires +RFI**	**Sires -RFI**	**Sign.**
Number of progeny	95	144	
Progeny carcass weight, kg	366	372	NS
Progeny carcass grade fat, mm	11.0	11.3	NS
Progeny ribeye area, cm^2	93.5	93.7	NS
Progeny marbling score	4.22	4.30	NS
Progeny yield grade	1.38	1.45	NS
Progeny lean meat yield, %	58.6	58.4	NS

NS, not significant, P>0.05

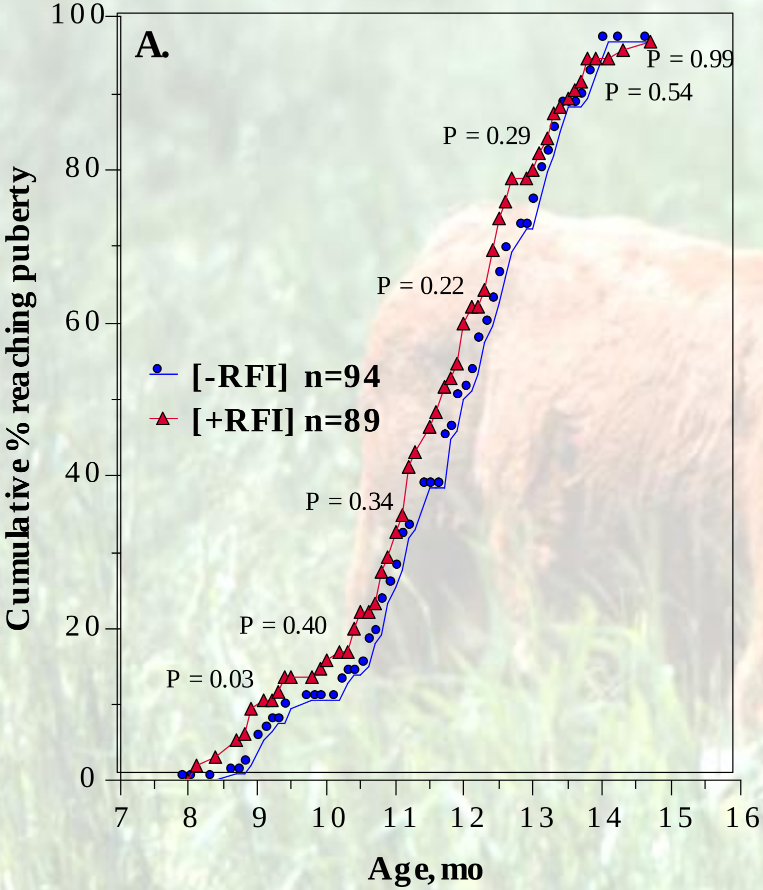
Individual Animal Feed Intake Facility,
Lacombe Research Centre, AB, Canada
Cow productivity & reproductive fitness

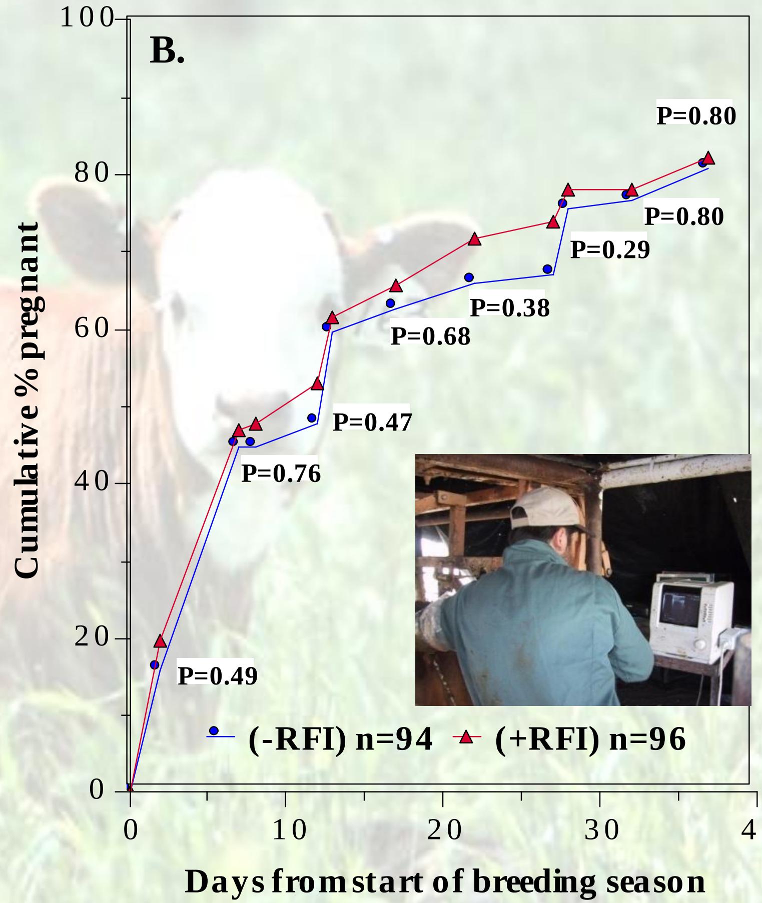


56.6% barley straw:40.0% silage
3.4% Feedlot sup (32% CP)
ad libitum twice daily

30% straw:70% grass hay (DM basis)
9.6% CP, 8.75 MJ ME/kg DM

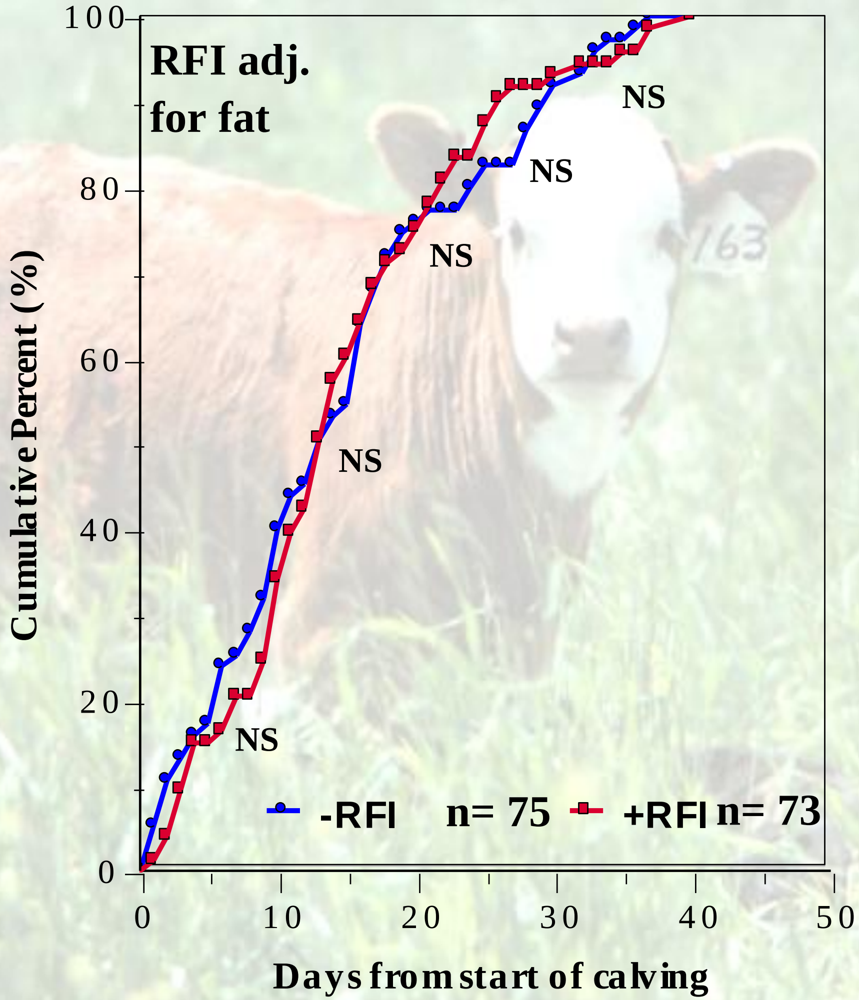
8. No effect of RFI_{fat} on age at puberty and pregnancy





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



Productivity traits in -RFI and +RFI first calf heifers

Trait	Heifer RFI $_{fat}$		
	-RFI	+RFI	sign.
Heifers exposed to breeding	98	92	
Calving difficulty, %	6.7	9.2	NS
Total calf death, %	5.3	11.8	
Calf death unknown, %	2.7	7.9	
Weaning rate, %	71.4	71.7	NS
Birth weight, kg	36.6	36.5	NS
Pre-weaning ADG, kg/day	0.98	0.99	NS
Weaning weight, kg	251	255	NS
Heifer productivity, kg/hd/yr	186	191	NS

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.

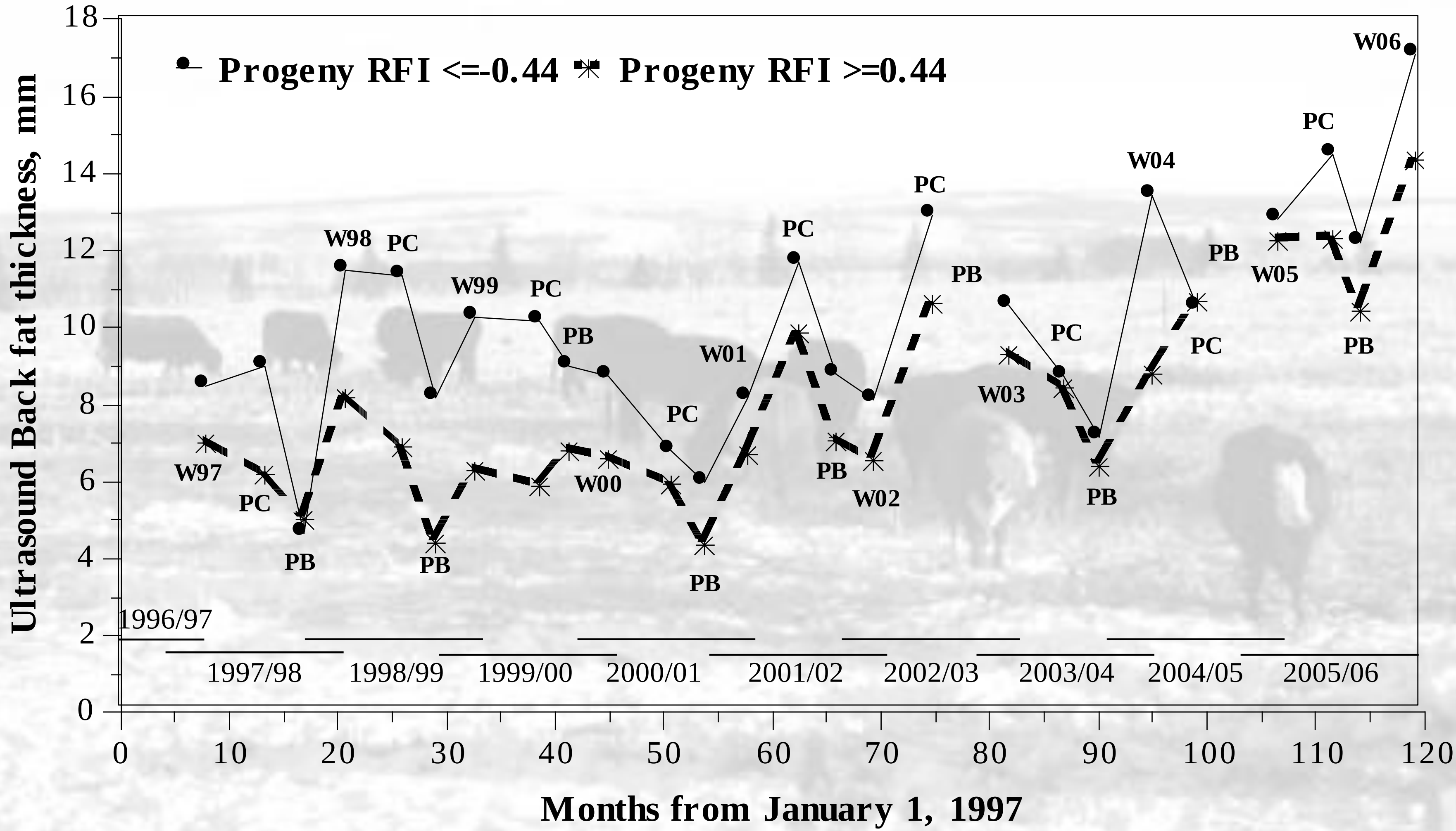
10. **No effect on pregnancy, calving or weaning rates**
No effect on kg calf weaned/cow exposed to breeding
(Arthur et al. 2005; Basarab et al. 2007)

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).

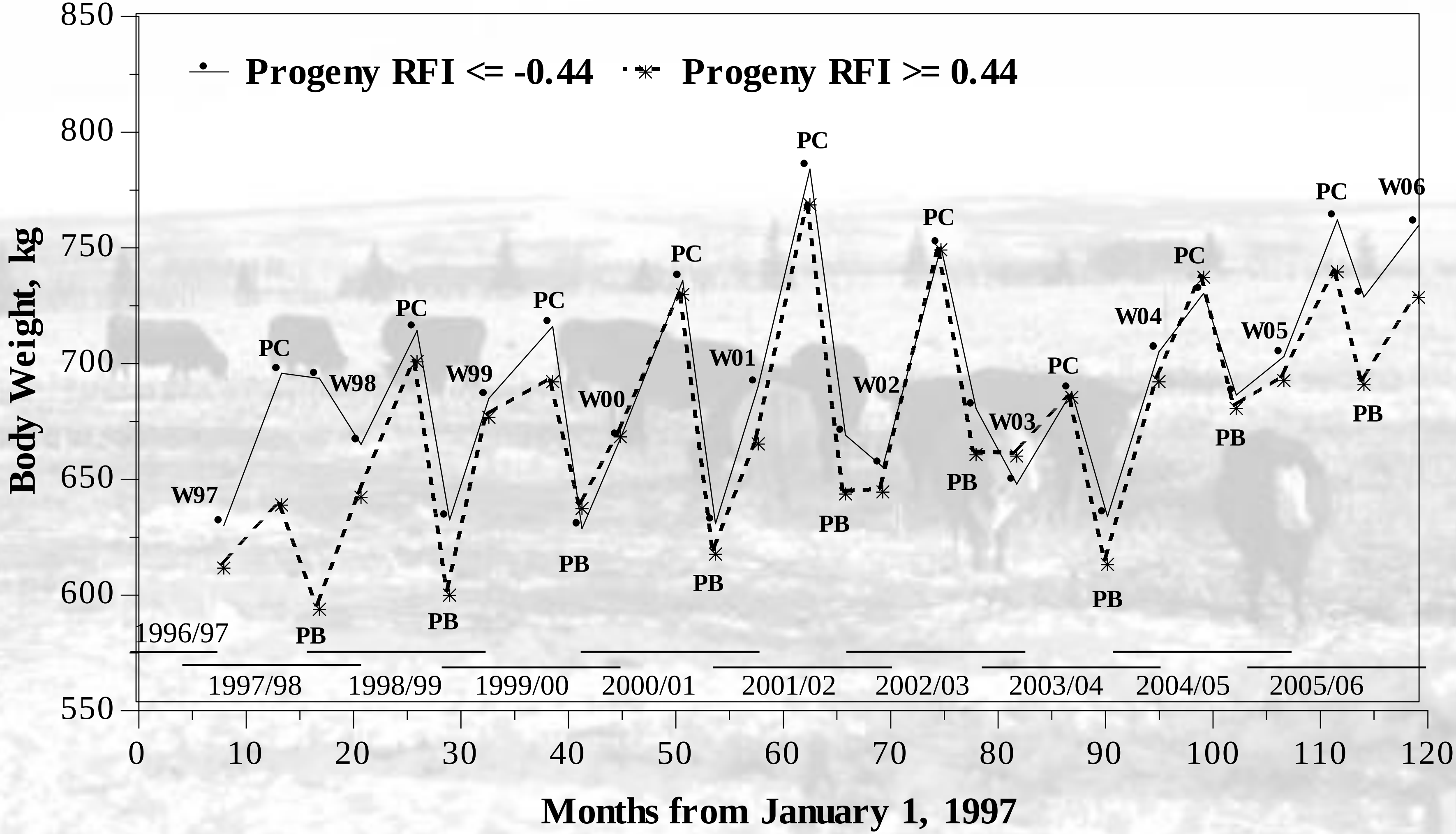
HIGH RFI cow E1245 (8 yr-old Hereford-Angus cow in the spring of 2004; RFI adj = 2.83 kg as fed/day; 2003 weight at weaning = 755 kg).

Note: cow RFI was adjusted for conceptus weight

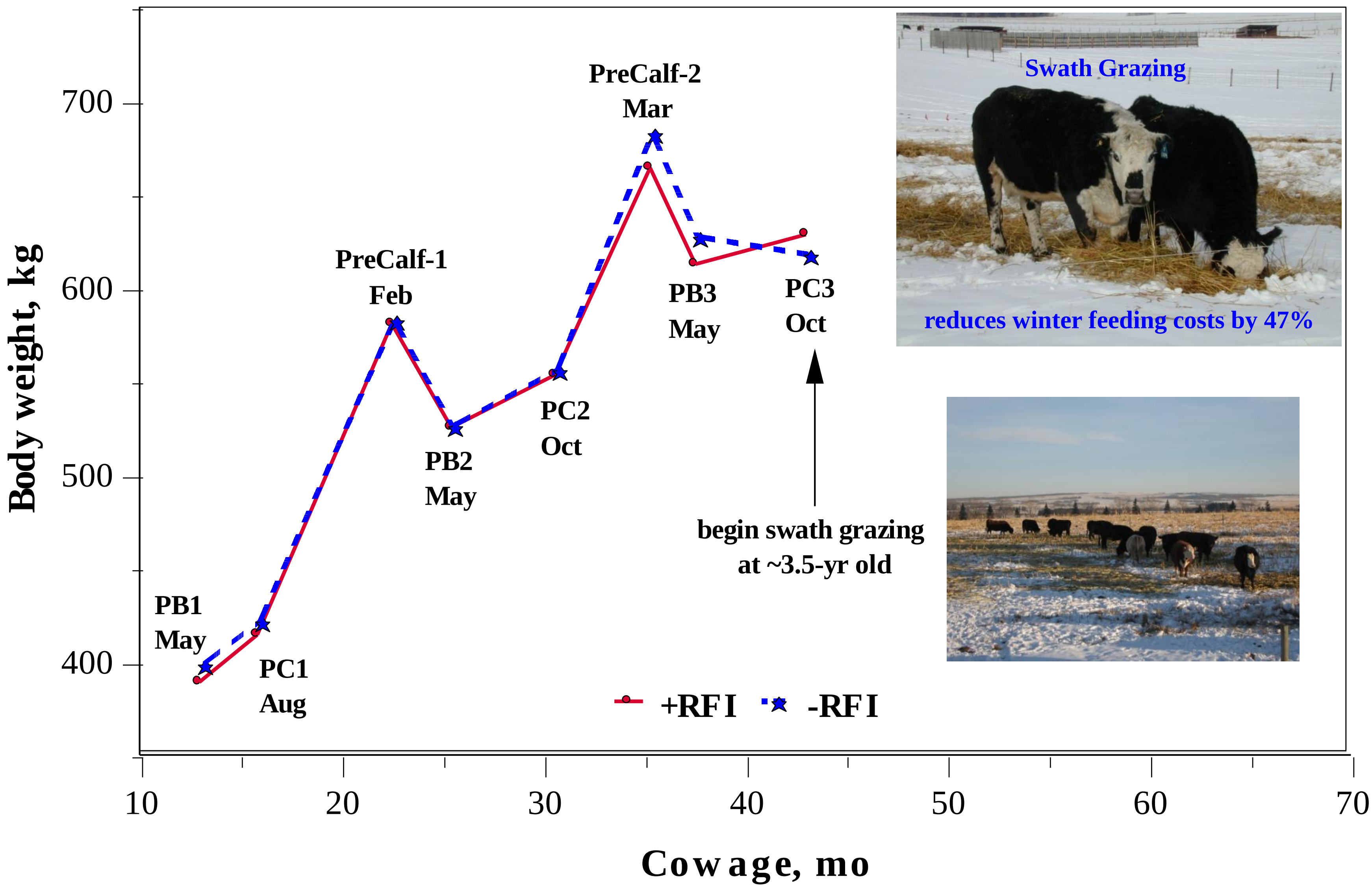
Long-term (1997 to 2006) ultrasound back fat thickness of cows that produced -RFI and +RFI progeny



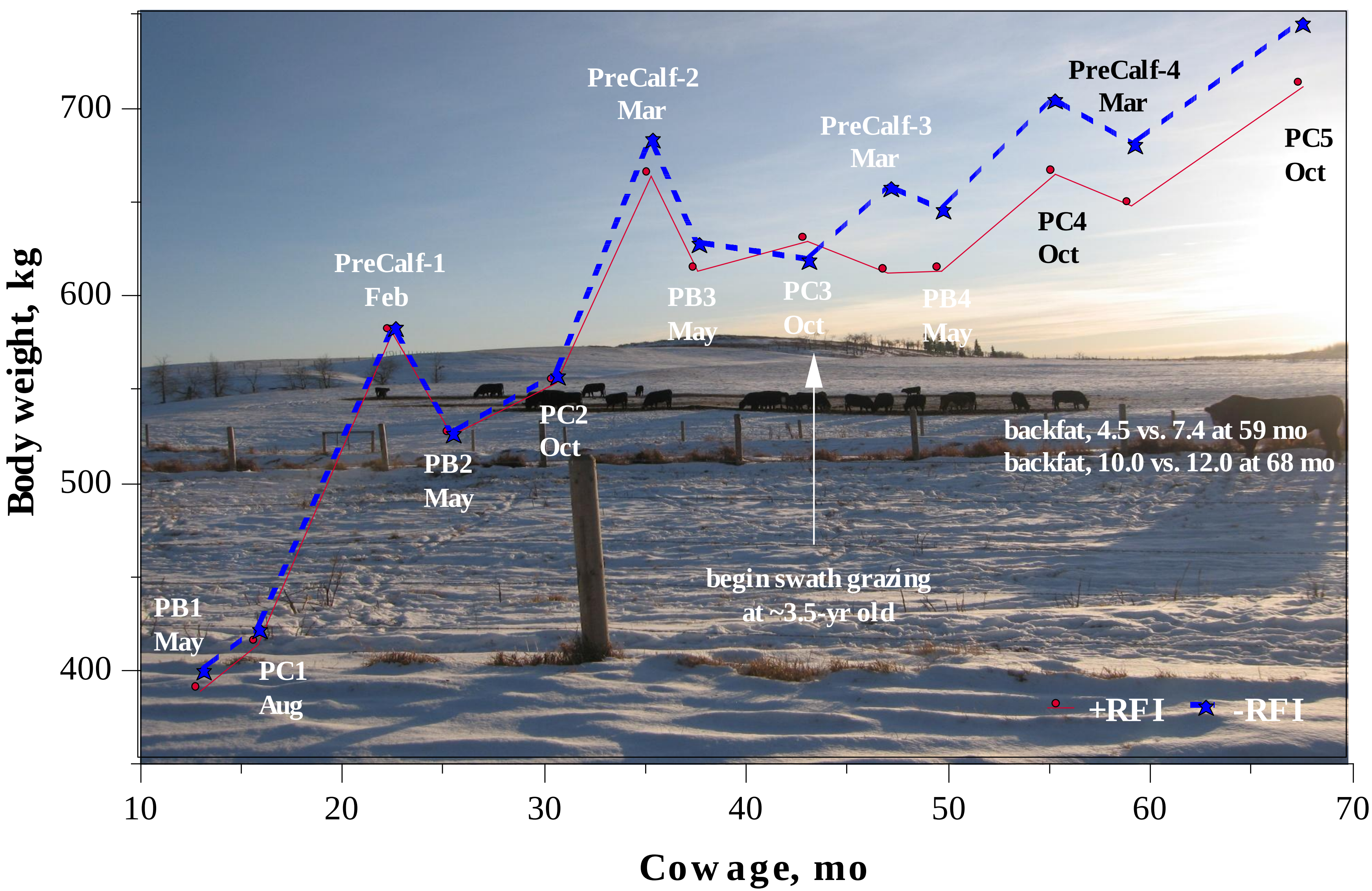
Long-term (1997-2006) body weight of cows that produced -RFI and +RFI progeny



Relationship between RFI$_{fat}$ as a heifer and subsequent changes in body weight as a cow



Relationship between RFI_{fat} as a heifer and subsequent changes in body weight as a cow



Repeatability of RFI in heifers to cows

Peter Lawrence, 2012, University College Dublin, Ireland

Traits	RFI measured as a heifer			sign.
	High	Med	Low	
DMI, kg/day				
12 mo of age	6.66^{a}	6.07^{b}	5.60^{c}	***
24 mo of age	8.62^{a}	8.12^{ab}	7.68^{b}	*
36 mo of age	9.66	8.95	8.96	NS

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)

$$FPI = 7.43\ EBV_{RFI\text{-}fat} + 37.38\ EBV_{ADG} + -0.12\ EBV_{WT365}$$

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).

$$MPI = \$3.00\ EBV_{WWTd} + \$2.70\ EBV_{WWTm} - \$0.49\ EBV_{COWT} + \$2.39\ EBV_{SURV3}$$

WWTd = direct weaning weight (30%)

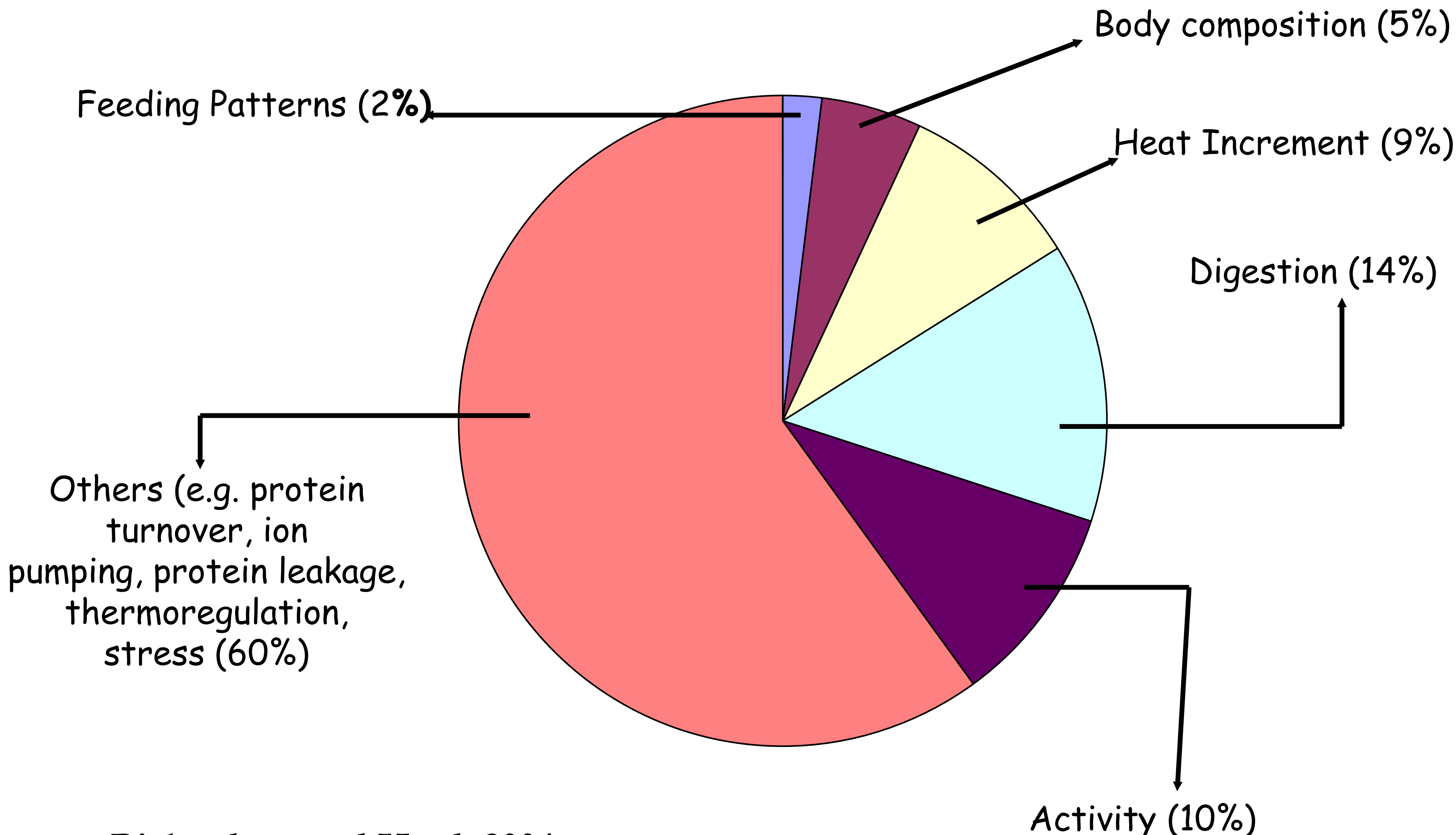
WWTm = maternal weaning weight (26%)

COWT = cow weight (17%)

SURV3 = 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

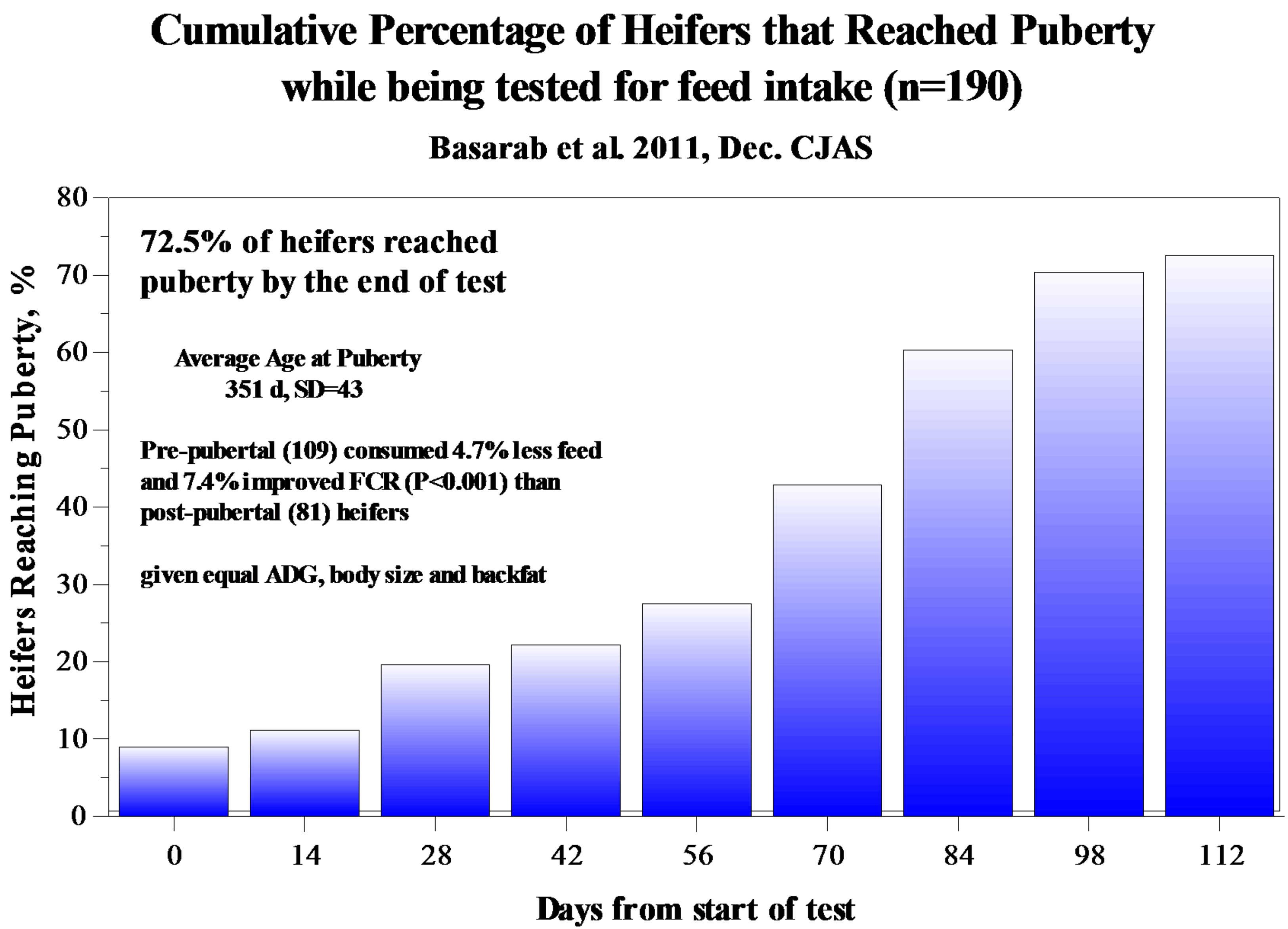


Richardson and Herd, 2004
Herd et al., 2004

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

Trait	HIGH RFI	LOW RFI	Sign. level	
RFI, kg DM/day	**1.25**	**-1.18**	**<0.001**	
Metabolic BW	**89.0**	**93.8**	**0.48**	
ADG, kg/day	**1.46**	**1.48**	**0.39**	
DMI, kg/day	**11.62**	**9.62**	**0.01**	**17.2%**
Fecal DM, g/kg DMI	**272**	**234**	**0.24**	
Urine, g/kg MWT	**56.3**	**45.5**	**0.25**	
Urine N, g/kg DMI	**8.60**	**7.13**	**0.19**	
CH_4, L/day	**152.2**	**120.1**	**0.04**	**21.1%**
CH_4, % of GEI	**4.28**	**3.19**	**0.04**	**25.5%**

LOW RFI: ME higher, HP lower, RE higher (kcal/kg MWT)

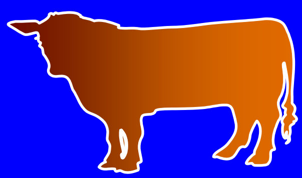


Feed intake tests favor later maturing heifers and bulls

Estimated Breeding value

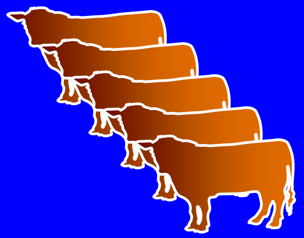
A Simple Example

-1.25 kg DM/d

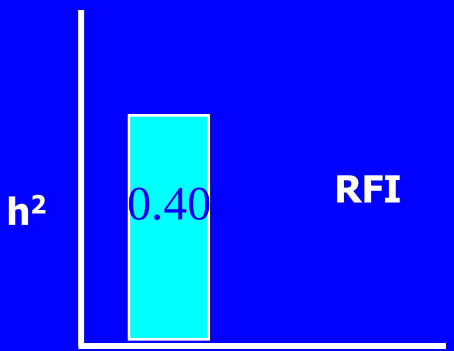


individual

0.0 kg DM/d



contemporary group average

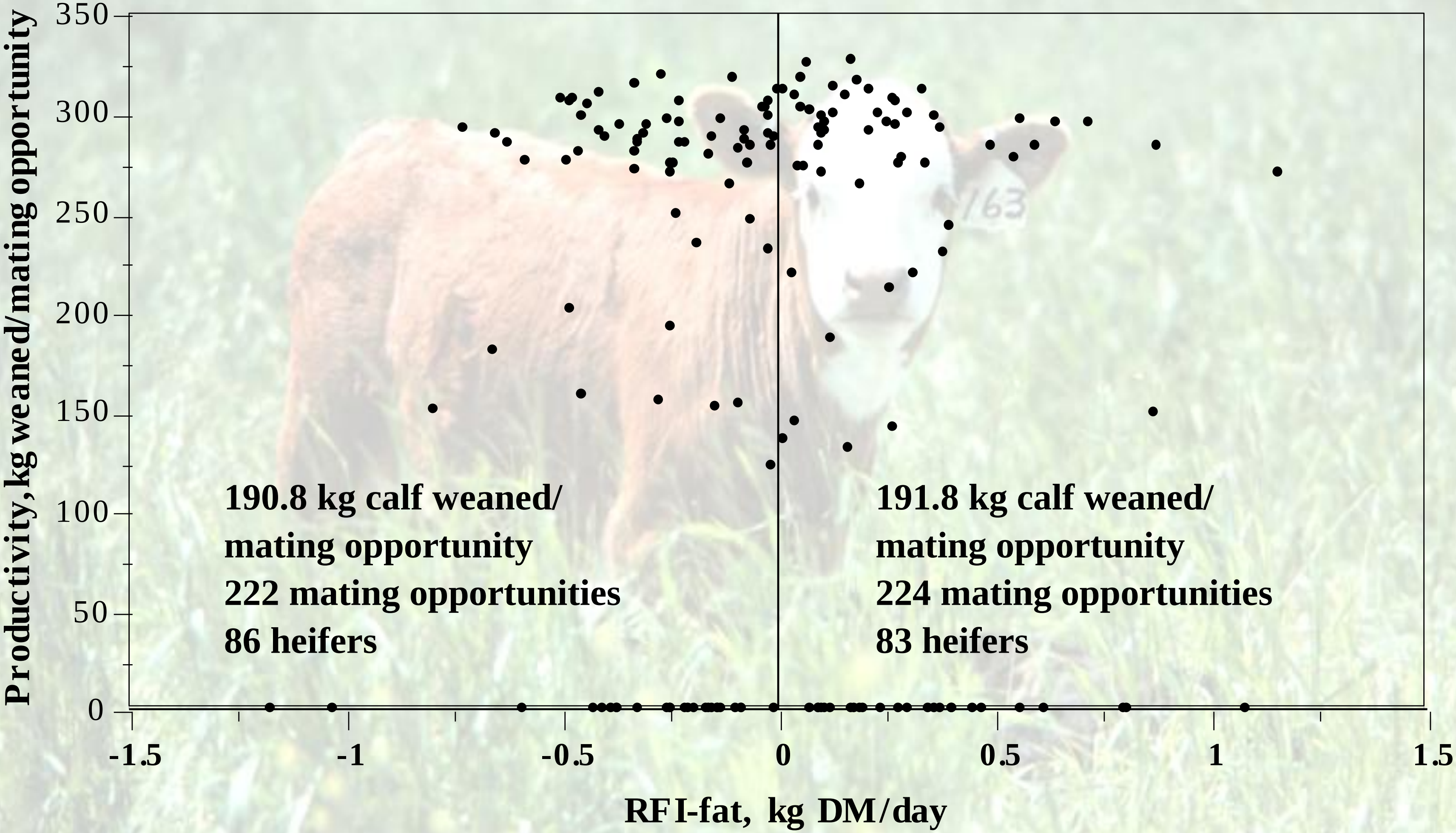


Accuracy=40%

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

Expected Progeny Difference =
(-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