Is There a Biological Basis for Variation in Feed Efficiency?

Beef Improvement Federation
2009 Annual meeting

Gordon Carstens and Monty Kerley

Departments of Animal Science
Texas A&M University and University of Missouri

AgriLIFE RESEARCH
Texas A&M System

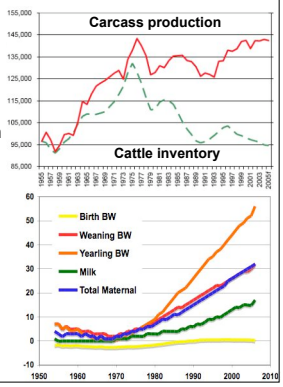
Beef Profitability:
Function of outputs and inputs

Productivity of US beef industry:

- **Beef production per total inventory has increased 80% in last 50 years** (Elam and Preston, 2004)

Productivity Drivers:

- **Nutrition** (grain-based programs)
- **Pharmaceutical technologies**
- **Reproductive technologies**
- **Pasture productivity**
- **Crossbreeding** (heterosis)
- **Selection** (EPDs for output traits)



Beef cattle selection for post-weaning growth (15 to 25 yrs)

Growth selection studies	Impact of growth selection on efficiency
Rust et al., '95	F:G ratio and Maintenance requirements were not favorably affected
Herd et al., '01	
Branco et al., '06	
Almedia et al., '07	

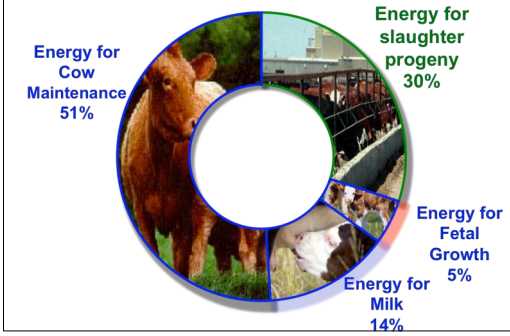
"Divergent selection for growth produced different-sized animals whose ability to convert feed to gain has not been altered"
Herd et al. (2001)

Selection for growth efficiency in broilers

Trait	1957 strain	2001 strain
Days to reach 4 lb	101	32
F:G ratio	4.42	1.47

Havenstein et al. (2003) concluded that 85 to 90% of these production efficiency gains were due to genetic selection, whereas the other 10 to 15% was due to improvements in nutrition and management

Feed energy budgets for integrated beef production systems



Genetics of maintenance energy requirements:
Between-breed Variation

Breed differences exist in cow maintenance efficiency:

1. Dairy breeds
2. Beef *Bos taurus* breeds
3. *Bos indicus* breeds

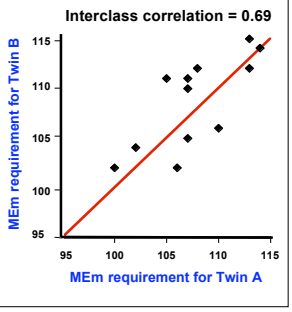
Breed	Ferrell & Jenkins (1984)	Byers et al. (1984)
Angus-Hereford	130	104
Charolais	129	--
Jersey	145	152
Simmental	160	--
Brahman	--	98

Genetics of maintenance energy requirements:
Within-breed variation

Heritability estimates for maintenance efficiency:

✓**Weight equilibrium study with twin calves** $h^2 = 0.89$
(Taylor & Young, 1968)

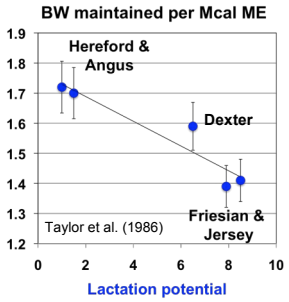
✓**Calorimetry study with monozygous twins**
$h^2 = 0.52$ (Hotovy et al., 1991)



Genetics of maintenance energy requirements:
Genetic antagonisms

Breed differences exist in cow maintenance efficiency:

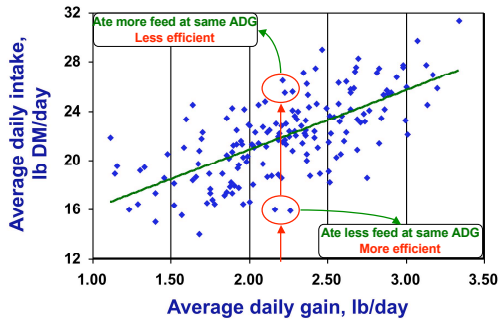
- **Genetic antagonisms between maintenance energy requirements and level of productivity (e.g., growth, milk)**



Residual Feed Intake in growing cattle

- ✓ **RFI is a measure of feed efficiency that quantifies the variance in feed intake *unrelated* to level of production (BW and ADG in growing cattle)**
- ✓ **Efficient animals are those that consume less feed than expected for a given BW and growth rate**
- ✓ **Given the RFI is independent of level of production, it is a useful trait to use to examine the biological mechanisms associated with variation in feed efficiency**

Relationship between feed intake and growth in steers



Comparison of steers with divergent RFI

Performance data during an 77-day growing trial:

538 lb	Initial body weight	535 lb
2.11 lb/d	ADG	2.16 lb/d
1502 lb	Expected feed intake	1509 lb
1717 lb	Actual feed intake	1232 lb
+215 lb	Residual feed intake	-277 lb

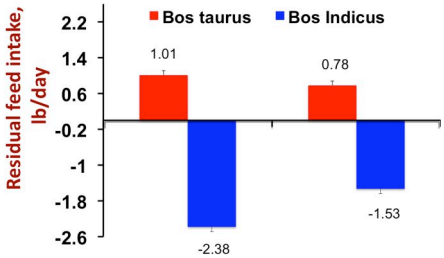
The more efficient steer (negative RFI) gained the same, but ate 485 lbs less feed than the less efficient steer (positive RFI)

Genetics of residual feed intake in growing bulls:
Between-breed variation

RFI Breed Rank	Breed (RFI, lb/day)
Inefficient	Angus (1.21)
↓	Simmental (0.37)
↓	Hereford (0.15)
↓	Charolais (0.00)
↓	Limousin (-0.77)
Efficient	Blonde d'Aquitaine (-1.17)

Schenkel et al. (2004)

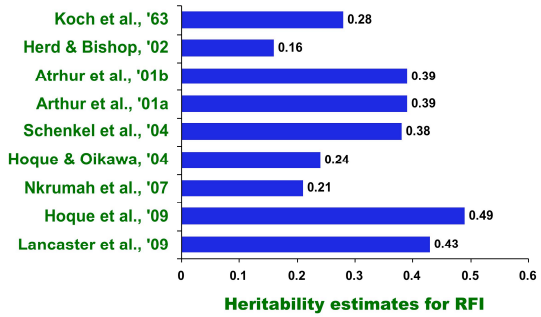
Genetics of residual feed intake in growing heifers:
Between-breed variation



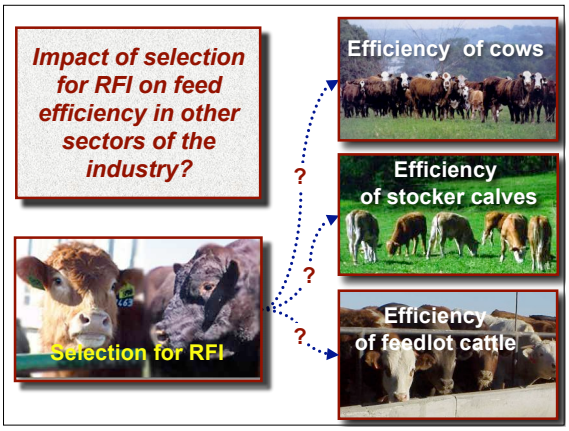
Riley et al. (2007)
Purebred Angus vs Purebred Brahman heifers

Randel et al. (2008)
F_1 Bos taurus vs F_1 Bos indicus heifers

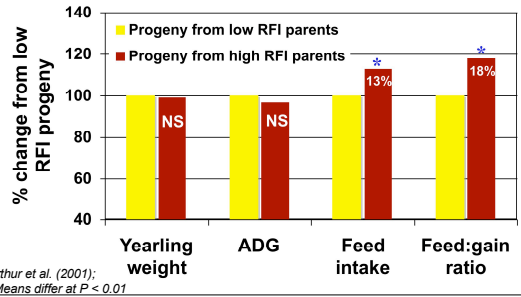
Within-breed genetic variation in RFI



Impact of selection for RFI on feed efficiency in other sectors of the industry?



Associations between selection for RFI and efficiency of feedlot progeny



Arthur et al. (2001);
**Means differ at P < 0.01*

Associations between feed efficiency in feedlot progeny and mature forage-fed cows

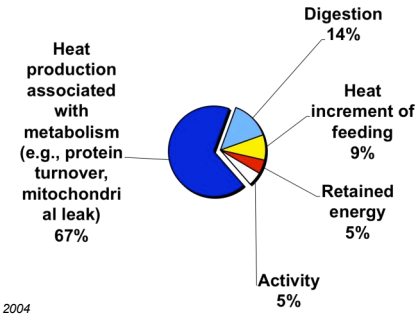
- ✓ Calves ranked by RFI phenotype on fed high-grain diet
- ✓ Intake of cows that produced calves with divergent RFI calves measured while fed high-roughage diet

	Calf RFI phenotype group		
Trait	Low	Medium	High
No. of calves tested	63	83	73
Calf RFI, lb/day	-1.7[a]	-0.20[b]	1.4[c]
No. of cows tested	26	40	45
Cow DM intake, lb/day	23.8[a]	24.9[a]	26.8[b]

[a,b,c]*Means differ at P < 0.05.*

Basarab et al., 2007

Biological basis for variation in RFI of beef cattle



Herd et al., 2004

Inter-animal variation in basal energy expenditures

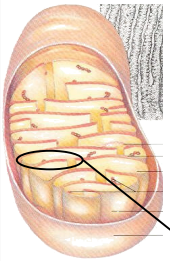
- Steers with high RFI had 10 and 24% greater energy expenditures than steers with low RFI phenotypes (Basarab et al., 2003; Nkrumah et al., 2006, respective)
- Variation in energy expenditures of animals with similar biotype may be related to cellular energy-consuming processes:
  - ✓Mitochondrial efficiency
  - ✓ion pumping associated with Na+/K+ATPase
  - ✓protein turnover
- Rolfe and Brown (1997) have estimated that these 3 cellular processes each contribute ≈ 20% to the total inter-animal variation in basal energy expenditures

Whole-animal O_2 consumption | Growing Brangus heifers with divergent RFI phenotypes

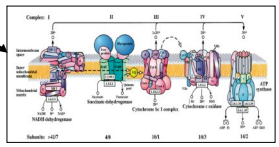
Trait	Low RFI	High RFI	Diff.
No. of heifers	5	7	n = 118
RFI, lb/day	**-1.8[a]**	**2.5[b]**	**+4.3**
Heart rate, beats/min	**89.6[a]**	**97.7[b]**	**9%**
Oxygen pulse rate, mL O_2/beat	**16.8[a]**	**20.0[b]**	**19%**
Energy expenditure, kcal/$BW^{0.75}$	**139[a]**	**168[b]**	**21%**

Paddock et al. (unpublished)

Animal variation in mitochondrial efficiency

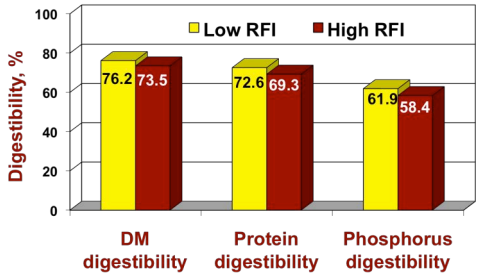


- **cell's "powerhouse"** responsible for capturing over 90% of the energy in the form of ATP
- Respiratory-chain coupling in mitochondria from muscle (Kolath et al., 2006) and liver (Lancaster et al., 2007) higher in steers with low RFI



Electron Transport Chain

Apparent digestibility | Growing Brangus heifers with divergent RFI phenotypes *(Krueger et al., '09)*

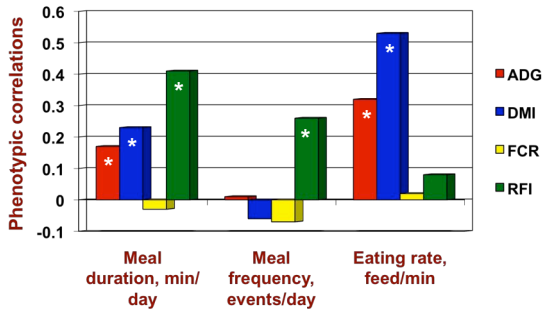


Apparent digestibility accounted for ≈ 19% of the difference in feed intake between heifers with divergent RFI

Activity-related energy expenditures in beef cattle

- **The energetic costs associated with eating, chewing and ruminating can account for 10 to 33% of the total metabolizable energy derived from forages (Susenbeth et al., 2003)**
- **Up to 30-40% of maintenance energy requirements can be due to physical activity**
- **Feeding behavioral traits found to be moderately heritable in beef cattle (Nkrumah et al., 2006)**
- **Variation in physical activity found to be associated with RFI in growing pigs and adult laying hens**

Feeding behavior traits | Growing Angus bulls with divergent phenotypes for RFI



*Lancaster et al. (2009); *Correlation differed from zero, P < 0.05.*

Feeding behavior traits | Growing Angus bulls with divergent phenotypes for RFI

Trait	Low RFI	High RFI	Difference
Number of bulls	107	99	N = 341
RFI, lb/day	**-1.9[a]**	**2.0[b]**	+3.9
ADG, lb/day	3.12	3.08	Not different
Meal duration, min/day	**93[a]**	**107[b]**	+14
Meal frequency, meals/dav	**7.3[a]**	**8.2[b]**	+0.9
Eating rate, lb/minute	0.21	0.22	Not different

Animal variance in feeding behavior traits accounted for 35% of variation in RFI

Lancaster et al. (2009)

Visceral organ mass | Finishing Angus calves with divergent RFI phenotypes

Trait	Low RFI	High RFI	Difference
Number of steers	16	16	N = 56
RFI, lb/day	**-1.7[a]**	**1.9[b]**	**+3.6 lb/day**
Carcass fat, %	**35.7[a]**	**37.5[b]**	**5.0%**
Non-carcass fat, % EBW	8.2	8.5	Not different
Empty gut weight, % EBW	**9.9[a]**	**10.4[b]**	**5.1%**
Liver weight, % EBW	1.35	1.35	Not different
Heart weight, % EBW	0.37	0.38	Not different

Animal variance in the proportion of visceral organs accounted for little of the variation in RFI

Ribeiro et al. (2008)

Ultrasound carcass traits | Growing Angus bulls with divergent RFI phenotypes

Trait	Low RFI	High RFI	Difference
Number of bulls	107	99	N = 341
RFI, lb/day	**-1.9[a]**	**2.0[b]**	**+3.9 lb/day**
ADG, lb/day	3.12	3.08	Not different
REA, in^2	11.9	12.1	Not different
12^{th} ribfat depth, in	**0.23[a]**	**0.26[b]**	**14%**
Intramuscular fat, %	3.23	3.22	Not different

Animal variance in carcass ultrasound traits accounted for 9% of variation in RFI

Lancaster et al. (2009)

Carcass composition | Finishing Santa Gertrudis steers with divergent RFI phenotypes

Trait	Low RFI	High RFI	Difference
Number of steers	39	37	N = 113
RFI, lb/day	**-2.3[a]**	**2.5[b]**	**+4.8 lb/day**
Hot carcass weight, lb	702	700	Not different
Backfat thickness, in	**0.38[a]**	**0.47[b]**	**24%**
Ribeye area, in^2	12.1	11.8	Not different
Marbling score	475	474	Not different
Carcass fat, %	**31.9[a]**	**34.5[b]**	**8.2%**
WB-shear force, lb	5.02	5.26	Not different

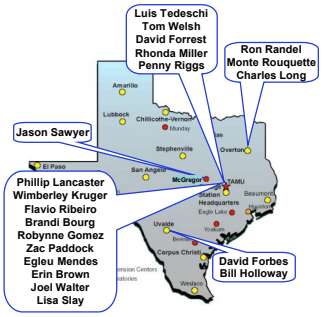
Animal variance in carcass fat content accounted for 15% of variation in RFI

Ribeiro et al. (2008)

Summary | Biological basis for RFI in beef cattle

- ✓ **RFI is favorably associated with biologically relevant processes (e.g., heat production, digestion, feeding behavior) that are linked to improved feed efficiency**
- ✓ **It is clearly evident that numerous biological processes underpin the variation in RFI**
- ✓ **While our understanding of RFI in growing cattle has advanced in recent years, our knowledge about the associations between RFI in growing calves and biological efficiency of mature cows is limited**
- ✓ **Better understanding of biological basis for RFI will help drive the search for indicator traits and major QTL associated with RFI**

Research Team at Texas A&M University



Funding and Industry Support:

- ✓ **USDA—Special Grants**
- ✓ **BARD program**
- ✓ **NCBA**
- ✓ **TCFA**
- ✓ **Camp Cooley Ranch**
- ✓ **King Ranch**
- ✓ **AgReserves Inc.**
- ✓ **Kallion Farms**
- ✓ **Beef Development Center**

Thanks for your attention!

AgriLIFE RESEARCH
Texas A&M System