Feeding behavior as indicator traits for genetic evaluation of feed intake

Advancements in Cowherd Efficiency

Beef Improvement Federation—2011

Gordon Carstens
Departments of Animal Science
Texas A&M University

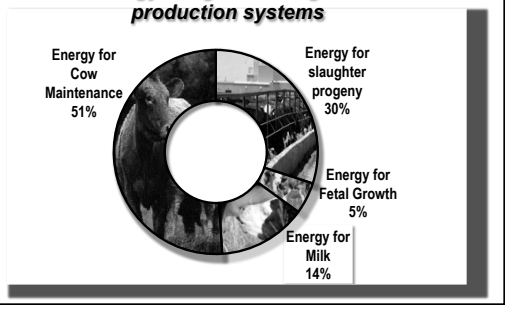
AgriLIFE RESEARCH
Texas A&M System

Presentation outline

- ✓ Perspective on cowherd efficiency
- ✓ Post-weaning feed efficiency
- ✓ Background on feeding behavior traits
- ✓ Associations between feeding behavior and feed utilization traits on growing cattle
- ✓ Associations between post-weaning RFI in heifers and cow efficiency

Beef Profitability | *Function of outputs and inputs*

Feed energy budget for integrated beef production systems



Genetics of maintenance energy requirements | *Between-breed variation*

Breed differences in cow maintenance energy requirements *(kcal/kg$^{.75}$/day)*:

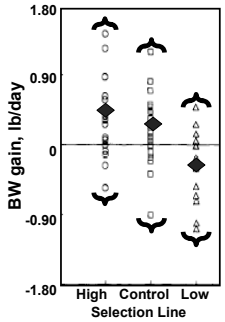
1. **Dairy breeds**
2. **Beef *Bos taurus* breeds**
3. ***Bos indicus* breeds**

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*

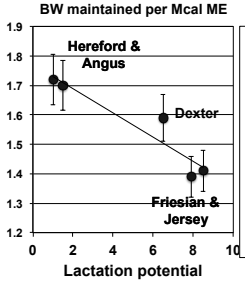
Within breed variation in maintenance efficiency:

- **Weight equilibrium study with twin calves; h^2 = 0.89** *(Taylor & Young, 1968)*
- **Calorimetry study with twin calves; h^2 = 0.52** *(Hotovy et al., 1991)*
- **Large between-animal variation in maintenance efficiency (CV = 16%) was observed** *(Herd, 1995)*



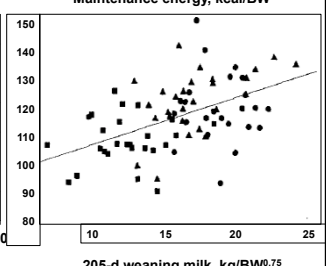
Genetics of maintenance energy requirements | *Associated with level of productivity*

Between breed
BW maintained per Mcal ME



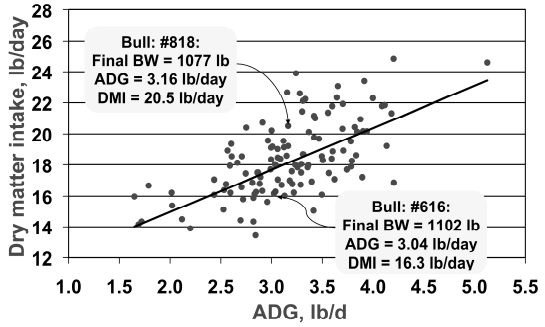
Taylor et al. (1986)

Within breed
Maintenance energy, kcal/BW$^{0.75}$



Montano-Bermudez et al. (1990)

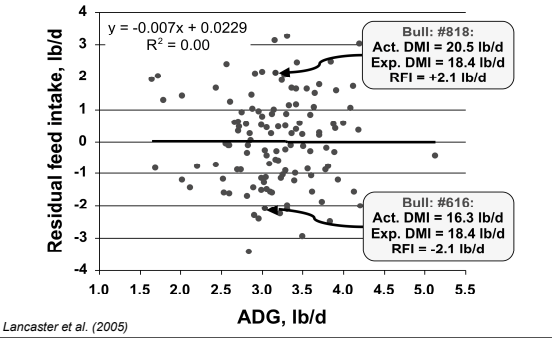
Relationship between feed intake and ADG in Angus bulls



Post-weaning feed efficiency | Residual feed intake in growing cattle

- ✓ **A large proportion of the variation in feed intake is *related* to the body weight *(BW)* and level of production**
- ✓ **RFI is a feed efficiency trait that quantifies variation in feed intake that is *unrelated* to *BW* and *ADG* in growing cattle**
- ✓ **RFI is moderately heritable, and is genetically independent of growth traits**

Relationship between RFI and ADG in Angus bulls



Lancaster et al. (2005)

Post-weaning feed efficiency | Residual feed intake in growing cattle

- ✓ A large proportion of the variation in feed intake is *related* to the body weight *(BW)* and level of production
- ✓ RFI is a feed efficiency trait that quantifies variation in feed intake that is *unrelated* to *BW* and *ADG* in growing cattle
- ✓ RFI is moderately heritable, and is genetically independent of growth traits
- ✓ **Therefore, RFI is a trait that *uncouples* genetics of efficiency from the genetics of production**
- ✓ **Given that 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**

Post-weaning RFI | Biological basis for between-animal variation in RFI

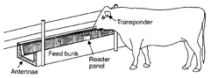
Calves with Low RFI (more efficient):	Reference
Lower heat production	Nkrumah et al. (2006)
Less methane produced	Hegarty et al. (2007)
Lower heart rates	Hafla et al. (2010)
Higher nutrient digestibility	Krueger et al. (2008)
Less carcass fat	Ribeiro et al. (2008)
More efficient muscle mitochondria	Kolath et al. (2006)
More efficient liver mitochondria	Lancaster et al. (2007)
Less time eating per day	Lancaster et al. (2009)

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 dietary energy derived from forages *(Susenbeth et al., 2003)*
- ✓ Up to 30-40% of total maintenance energy requirements can be due to physical activity
- ✓ Feeding behavioral traits found to be moderately heritable in beef cattle *(Robinson and Oddy, 2004; Nkrumah et al., 2007)* and favorably correlated with RFI in beef cattle *(Lancaster et al., 2009)*

Feeding behavior traits | Methods to measure feeding behavior in cattle

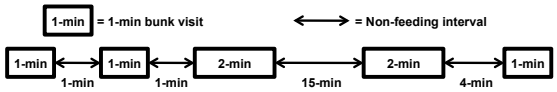
- ✓ Electronic feeding behavior system used passive RFID technology *(behavioral data only; GrowSafe Systems Ltd.)*
- ✓ Electronic feed-intake systems based on passive RFID technology *(intake and behavioral data)*
  - GrowSafe
  - Insentec
  - Pen pointer



GrowSafe feeding behavior system

- ✓ Future systems using high-frequency active-RFID technology *(e.g., Cattle Traq)* will be able to collect feeding behavior data from individual animals fed in large group pens

Feeding behavior traits | Definition of bunk visit (BV) traits



Summary of BV data:
- BV frequency = 5 events
- BV duration = 7 min

Mendes et al. (2011)

Feeding behavior traits | Impact of RFI on bunk visit traits in steers—Rex Ranch

Data from 2 studies with steers (N = 340)	Mean	SD	Low RFI (n = 92)	High RFI (n = 98)	High vs Low
RFI, lb/day	0.00	1.74	-2.01	1.90	--
ADG, lb/day	3.63	0.55	3.59	3.62	ND
DM Intake, lb/day	23.8	2.9	**21.7[a]**	**25.5[b]**	18%
F:G ratio	6.69	1.4	**6.22[a]**	**7.24[b]**	16%
BV frequency, events/d	59.5	18.0	**53.1[a]**	**65.4[b]**	23%
BV duration, min/day	62.6	13.6	**54.2[a]**	**69.6[b]**	28%

†Low and high RFI steers were ± 0.50 SD from mean RFI.
[a,b]Means differ at P < 0.001.

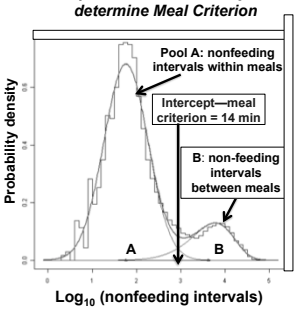
Walter et al. (2011)

Feeding behavior traits | Definition of meal traits

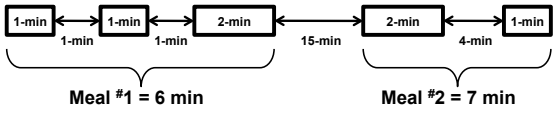
Meal—cluster of bunk visits for which the interval lengths between BV *(non-feeding intervals)* is less than the meal criterion

Meal Criterion—length of the longest non-feeding interval between BV that is still part of a meal

Two-pool distribution analysis to determine Meal Criterion



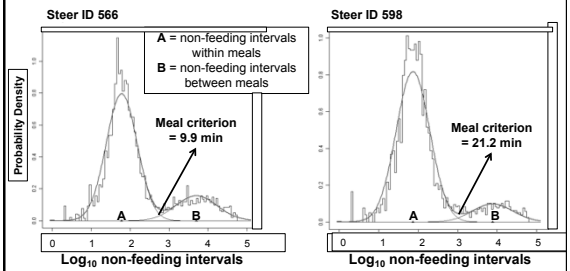
Feeding behavior traits | Definition of meal traits | Assume meal criteria = 14 min



Summary of BV data:
- BV frequency = 5 events
- BV duration = 7 min

Summary of meal data:
- Meal frequency = 2 events
- Meal duration = 13 min
- BV per meal = 2.5

Feeding behavior traits | Two-pool distribution analysis to compute individual-animal meal criterion



Mean meal criterion = 19 ± 10 min (minimum = 4; maximum = 60 min)

Rex Ranch steers | Feeding behavior correlations with DMI and feed efficiency traits

Data from 2 studies with steers (N = 340)	DMI	F:G	RADG	RFI
BV frequency, events/day	**0.31**	**0.26**	-0.06	**0.52**
BV duration, min/day	**0.36**	**0.30**	-0.09	**0.53**
Meal criterion, min	-0.08	**-0.19**	**0.14**	**-0.22**
Meal frequency, events/day	0.08	0.05	-0.02	**0.14**
Meal duration, min/day	**0.20**	0.07	0.07	**0.27**
Meal eating rate, g/min	**0.30**	0.10	-0.09	**0.11**

*Correlations in **BOLD** different from zero P < 0.05.*

Walter et al. (2011)

Feeding behavior traits | Impact of RFI on meal traits in steers—Rex Ranch

Data from 2 studies with steers (N = 340)	Mean	SD	Low RFI (n = 92)	High RFI (n = 98)	High vs Low
DM Intake, lb/day	23.8	2.9	**21.7^{a}**	**25.5^{b}**	18%
Meal criterion, min	19.1	9.9	**21.5^{a}**	**17.7^{b}**	-18%
Meal frequency, #/day	5.00	1.9	**4.70**	**5.10**	*P = 0.09*
Meal duration, min/day	131	25	**122^{a}**	**140^{b}**	15%
Meal eating rate, g/min	84.0	3.9	83.4	85.3	ND

†Low and high RFI steers were ± 0.50 SD from mean RFI.
^{a,b}Means differ at P < 0.001.

Walter et al. (2011)

Feeding behavior traits | Impact RFI on feeding behavior traits in heifers—Deseret Ranch

Data from 6 studies with heifers (N = 878)	Mean	SD	Low RFI (n = 239)	High RFI (n = 245)	High vs Low
DM Intake, lb/day	22.2	4.0	**19.5^{a}**	**24.6^{b}**	26%
BV frequency, events/d	59.6	16.0	**55.2^{a}**	**64.7^{b}**	17%
BV duration, min/day	55.7	20.3	**48.0^{a}**	**65.8^{b}**	37%
Meal criterion, min	11.48	0.03	11.63	11.38	ND
Meal frequency, #/day	7.60	3.76	7.78	7.81	ND
Meal duration, min/day	131	40	**121^{a}**	**144^{b}**	19%
Meal eating rate, g/min	86.0	39	83.2	83.9	ND

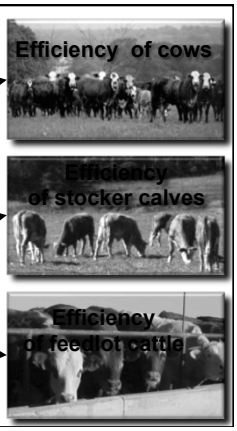
†Low and high RFI heifers were ± 0.50 SD from mean RFI.
^{a,b}Means differ at P < 0.001.

Bailey et al. (2011)

Summary points | Feeding behavior in growing cattle

- ✓ Cattle with divergent RFI phenotypes have distinctive behavioral patterns associated with feeding activities
- ✓ Growing cattle with low RFI (efficient):
  - 15-19% fewer daily bunk visit events
  - Spent 18-23 min less time each day consuming meals
  - Similar meal frequencies and meal eating rates
  - 17% fewer BV events per meal
  - Steers waited 4 min longer to initiate a new meal *(longer meal criterion)*
- ✓ Feeding behavioral traits likely reflect biological processes that underpin genetic variation in energy metabolism and(or) metabolic signals that control of hunger and satiety

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



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 progeny	63	83	73
Calf RFI, lb/day	**-1.7^{a}**	**-0.2^{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}**

Cow RFI positively correlated with BV frequency (0.50) and BV duration (0.36)

Basarab et al. (2007); ^{a,b,c}Means differ at P < 0.05.

Bonsmara heifers | Associations between heifer RFI and cow DMI and performance

- ✓ Bosmara heifers (N ≈ 60 per yr) ranked by RFI phenotype
- ✓ Heifers with lowest and highest RFI (n = 12/yr) retained for breeding

Two-year summary	Heifer RFI Low	High
No. of heifers	24	24
RFI, lb/day	**-2.13[a]**	**1.96[b]**
Initial BW, lb	711	722
ADG, lb/day	3.12	3.48
DM Intake, lb/d	**16.0[a]**	**20.0[b]**
F:G ratio	**5.84[a]**	**7.00[b]**

Hafla et al. (2011); [a,b]Means differ at P < 0.01.

Divergent RFI heifers | Impact on heart rate (HR) and physical activity of Bonsmara heifers

Confinement study:	Heifer RFI Low	High
HR, beats/min	**90.7[a]**	**92.8[b]**
Steps, counts/hour	45.2	41.5
Standing, min/hour	28.3	26.8
Grazing study:		
HR, beats/min	**74.7[a]**	**77.7[b]**
Steps, counts/hour	196	186
Standing, min/hour	30.7	30.3

Polar® heart rate transmitters and monitors

IceTag® tri-axial accelerometers

Hafla et al. (2011); [a,b]Means differ at P < 0.05; n = 6.

Divergent RFI heifers | Impact on DMI and BSC of mid-gestation Bosmara females

Cow traits	Heifer RFI Low	High
No. of females	20	22
Initial BW, lb	1,087	1,067
ADG, lb/day	1.12	1.36
Forage DMI, lb/day	**19.8[a]**	**25.6[b]**
Final BCS	4.93	5.01
Rump fat depth, in	0.46	0.44

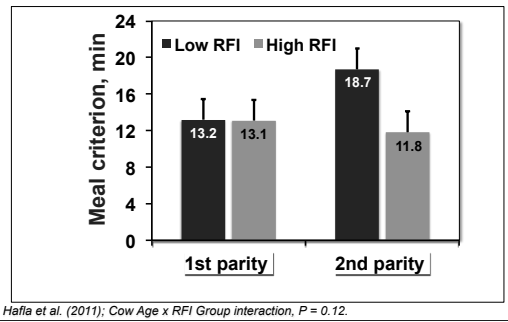
Hafla et al. (2011); [a,b]Means differ at P < 0.01.

Divergent RFI heifers | Impact on feeding behavior of mid-gestation Bosmara females

Cow traits	Heifer RFI Low	High
No. of females	20	22
Bunk visit (**BV**) frequency, events/day	115	119
BV duration, min/day	**149[a]**	**198[b]**
Meal frequency, #/day	13.2	11.9
Meal duration, min/day	335	360
Meal eating rate, g/min	**27.4[a]**	**33.0[b]**
Meal criterion, min	15.9[x]	12.5[y]

Hafla et al. (2011); [a,b]Means differ at P < 0.01; [x,y]P = 0.12.

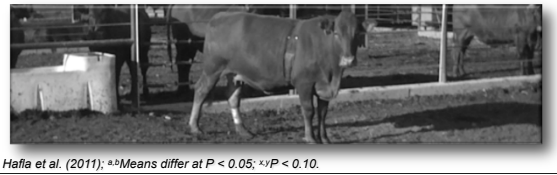
Divergent RFI heifers | Impact on meal criterion of mid-gestation Bosmara females



Hafla et al. (2011); Cow Age x RFI Group interaction, P = 0.12.

Divergent RFI heifers | Impact on HR and physical activity of mid-gestation Bosmara females

Cow traits	Heifer RFI Low	High	Cow traits	Correlations with HR
HR, beats/min	**65.8[a]**	**71.2[b]**	BV frequency	**0.32**
Steps, counts/h	109[x]	94[y]	BV duration	**0.32**
Standing, min/h	33.7	33.1	Meal duration	**0.40**



Hafla et al. (2011); [a,b]Means differ at P < 0.05; [x,y]P < 0.10.

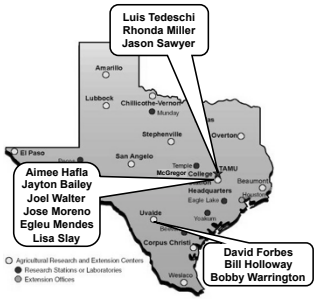
Summary points | Associations between heifer RFI and cow efficiency

- ✓ Mid-gestation females with low RFI as heifers:
  - Consumed 23% less forage, but had similar BW, BCS and rump fat depth *(all successfully calved)*
  - Spent 50 min less time at the feed bunk each day
  - Had 17% slower eating rates, but similar meal frequencies
  - 2nd parity cows waited 7 min longer to start new meals *(meal criterion)*
  - Had 8% lower heart rates, suggesting lower heat production
- ✓ Phenotypic RFI during heifer development appears to be highly associated with efficiency of forage utilization in mid-gestation 1st and 2nd parity females

Summary points | Feeding behavior as an indicator trait for feed utilization

- ✓ In growing cattle, RFI is favorably associated with biologically relevant processes *(heat production, digestion, composition of growth, feeding behavior)* that are linked with feed efficient phenotypes
- ✓ These same biological processes do not appear to be similarly associated with residual gain (**RADG**)
- ✓ Growing cattle and mid-gestation females with divergent RFI phenotypes have distinctive behavioral patterns associated with feeding activity
- ✓ In the absence of intake phenotypes, feeding behavior parameters may be useful indicator traits for genetic evaluation of intake and feed utilization traits

Research Team at Texas A&M University



Funding and Industry Support:

- ✓ **USDA—Special Grants**
- ✓ **BARD program**
- ✓ **TCFA**
- ✓ **AgReserves Inc.**
- ✓ **King Ranch**

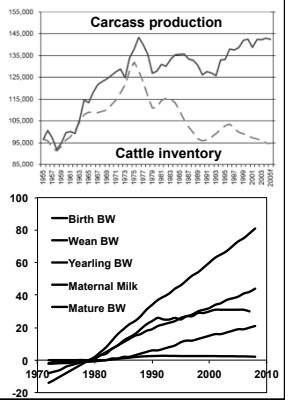
Beef Profitability: Function of outputs and inputs

Productivity of US beef industry:

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

Productivity Drivers:

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



Beef Profitability | Impact of postweaning selection for growth on feed efficiency of progeny

Growth selection studies†	Breed	Impact of selection on feed efficiency of progeny
Irgang et al. (1985)	Herford	Feed:Gain ratio and(or) maintenance requirements were not favorably affected by selection for growth
Herd et al. (1991)	Angus	
Rust et al. (1995)	Herford	
Branco et al. (2006)	Nelore	
Almedia et al. (2007)	Nelore	

†*Selection for growth traits occurred for 15-25 years.*

"Divergent selection for growth produced different-sized animals whose ability to convert feed to gain has not been altered" **Herd et al. (1991)**