Impact of Selection for Improved Feed Efficiency

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Importance of Feed Efficiency

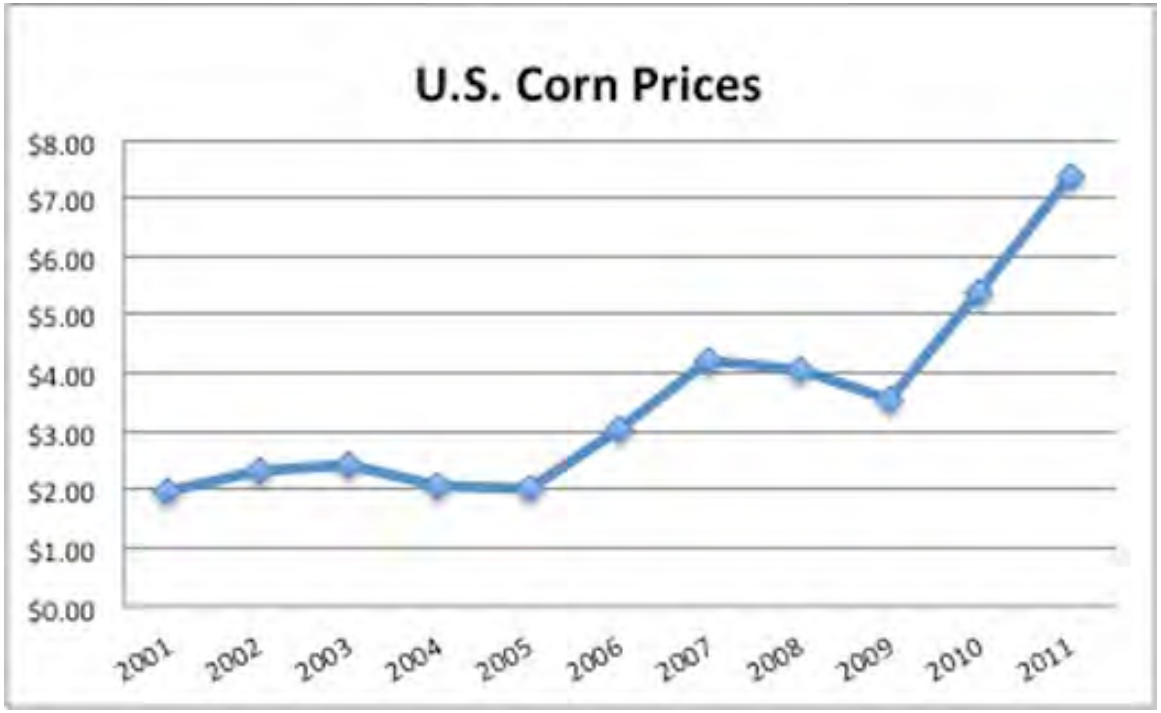
- By 2050, the world population is expected to increase 34%
  - Require 70% more food from existing natural resources

- Due to their ability to utilize cellulose, beef cattle produce high-quality human food from non-arable land
  - Energetic efficiency is very low ~40%

FAO, 2009

Importance of Feed Efficiency

- Reducing feed inputs per unit of production could significantly improve profitability by 9 to 33% (Archer et al., 2004)



http://news.medill.northwestern.edu/chicago/news.aspx?id=187103

Importance of Feed Efficiency

- Maintenance requirements are largest energetic cost of beef production (71%)
  - Mature cow uses 93% of feed intake for maintenance
  - Breeding herd accounts for 65% of maintenance requirements for beef production

Johnson, 1984

Feed Efficiency Traits

- Feed conversion ratio (FCR):
  - Typical trait used to measure feed efficiency
  - Ratio of DMI to ADG
- Partial efficiency of growth (PEG):
  - Ratio of ADG to DMI for growth
- Residual feed intake (RFI)
  - Actual feed intake minus expected feed intake for body size and growth rate

Feed Efficiency Traits

- Kleiber ratio (KR):
  - Ratio of ADG to metabolic BW
- Relative growth rate (RGR):
  - 100 x (log final BW – log initial BW) ÷ days
- Residual gain efficiency (RGE):
  - Actual ADG minus expected ADG based on its size and feed intake

Feed Efficiency Traits

Feed Efficiency Trait	Favorable Phenotype	Heritability[1]
Feed Conversion Ratio (**FCR**)	Low	0.29 to 0.46
Residual Feed Intake (**RFI**)	Low	0.38 to 0.47
Partial Efficiency of Growth (**PEG**)	High	0.39 to 0.56
Kleiber ratio (**KR**)	High	0.21 to 0.31
Relative Growth Rate (**RGR**)	High	0.24 to 0.33
Residual Gain Efficiency (**RGE**)	High	0.31

[1]Arthur et al., 1997, 2001a, 2001b; Schenkel et al., 2004; Nkrumah et al., 2007; Lancaster et al., 2009; American Angus Assoc.

Phenotypic Relationships with Feed Intake and Growth

Trait	FCR	PEG	KR	RGR	RGE	RFI
DMI	0.48*	-0.69*	0.15	0.02	--	0.60*
	0.47*	--	--	--	--	0.81*
	0.30*	-0.30*	--	--	--	0.64*
	-0.01	-0.37*	0.37*	0.23*	0.01	0.60*
ADG	-0.54*	-0.14*	0.83*	0.68*	--	0.01
	-0.58*	--	--	--	--	-0.06
	-0.69*	0.35*	--	--	--	0.00
	-0.72*	0.38*	0.89*	0.73*	0.74*	0.00

*Correlation coefficient is different from zero at $P < 0.05$

Relationship of RFI with Other Feed Efficiency Traits

Study	Corr.	FCR	PEG
Arthur et al., 2001a	Phenotypic	0.57*	-0.65*
	Genetic	0.85*	-0.94*
Schenkel et al., 2004	Phenotypic	0.76*	--
	Genetic	0.69*	--
Nkrumah et al., 2007	Phenotypic	0.52*	-0.83*
	Genetic	0.62*	-0.87*
Lancaster et al., 2009	Phenotypic	0.59*	--
	Genetic	0.93*	--

*Correlation coefficient is different from zero at $P < 0.05$

Summary of Feed Efficiency Traits

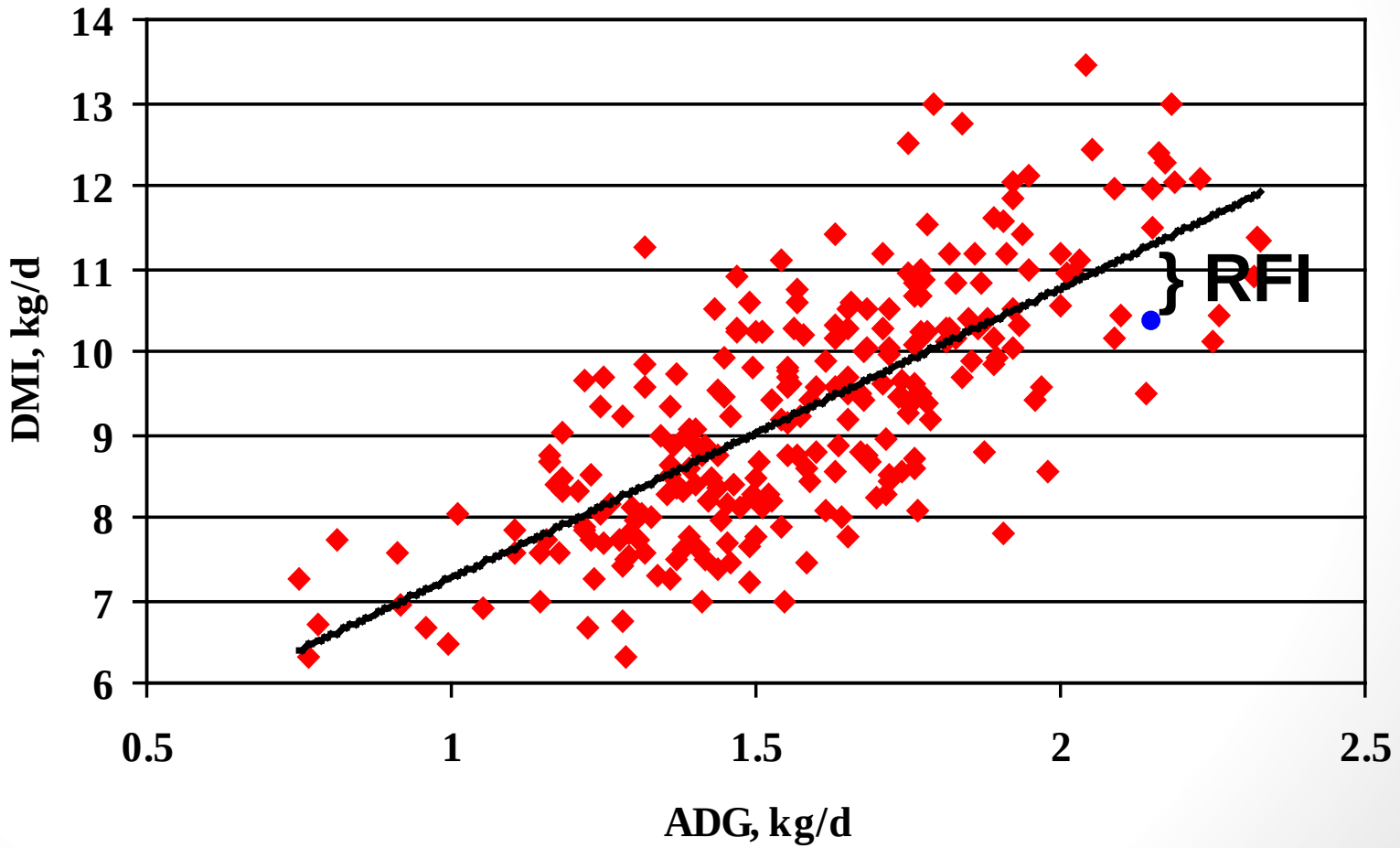
- Residual feed intake is only trait independent of growth
  - Will not result in correlated increase in cow mature size
  - Put selection pressure solely on feed intake

What is Residual Feed Intake (RFI)

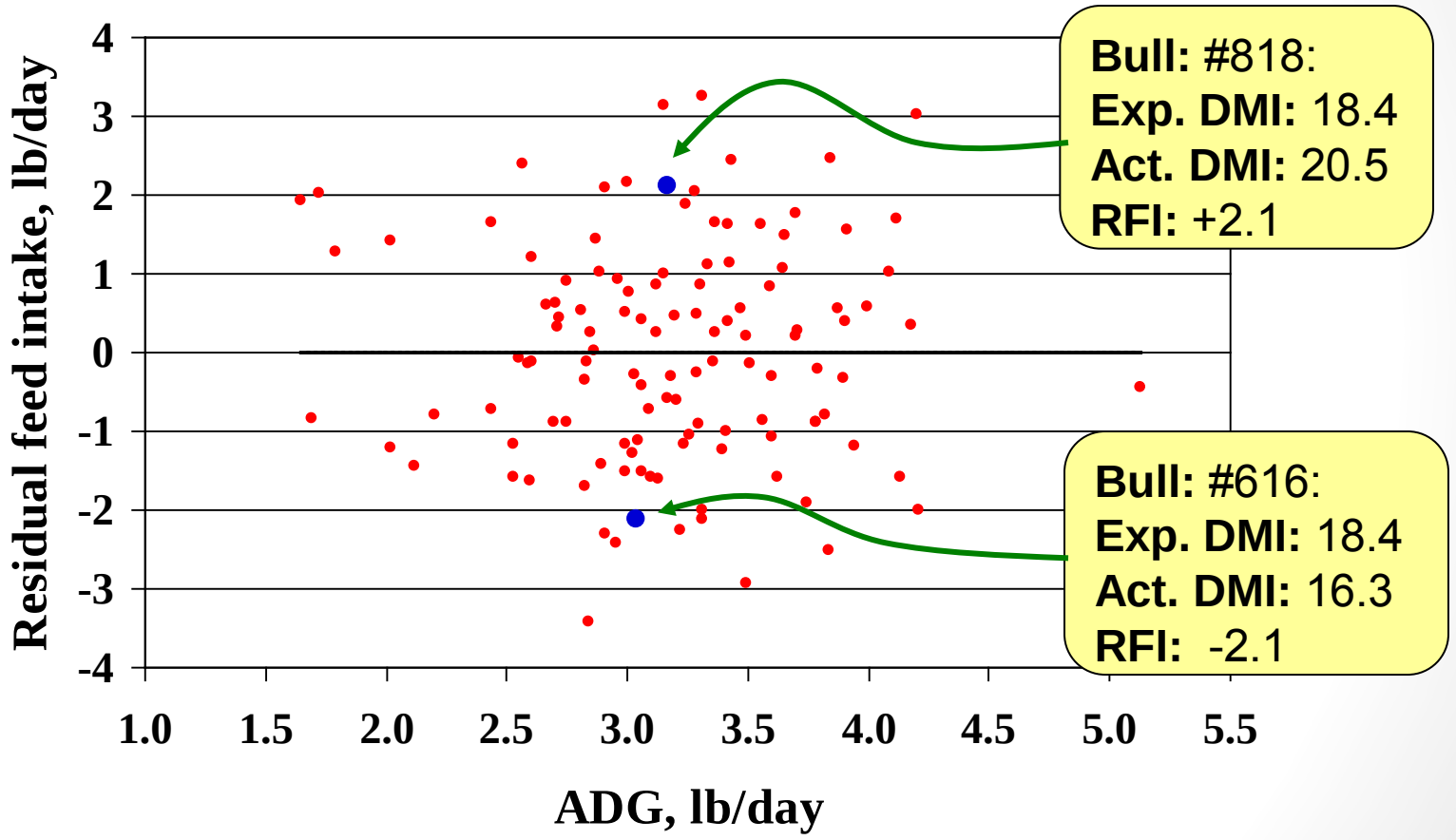
- Net Feed Intake or Net Feed Efficiency
  - Proposed by Koch et al. (1963) as alternative measure of feed efficiency not related to growth rate
  - Measures variation in feed intake beyond that needed to support maintenance and growth requirements
  - The difference between an animal's actual feed intake and the amount of feed an animal is expected to eat based on its size and growth rate

Residual Feed Intake

$$DMI = \beta_0 + \beta_1 * BW^{0.75} + \beta_2 * ADG + \varepsilon(RFI)$$

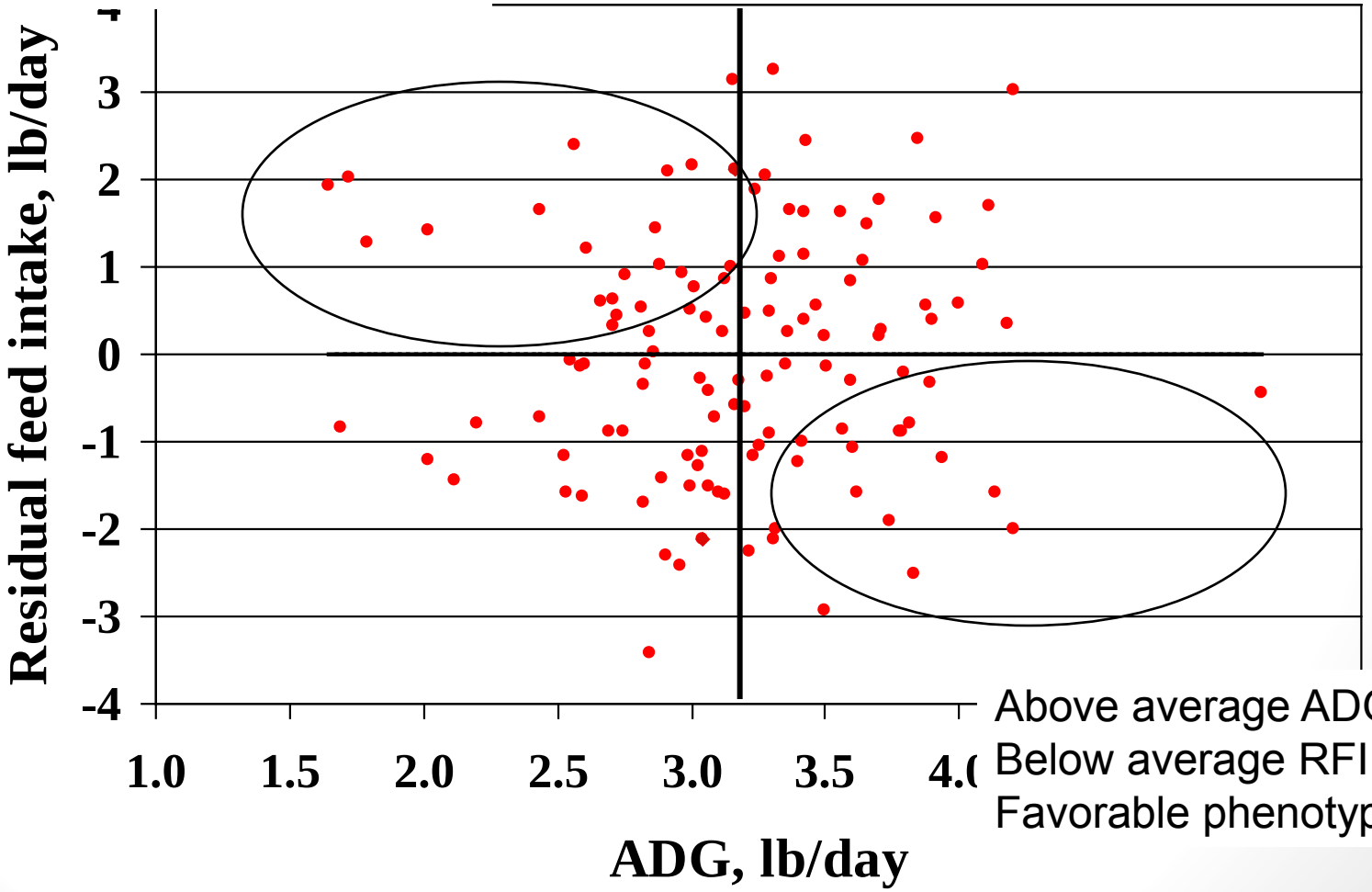


Residual Feed Intake



Selecting for Residual Feed Intake

Below average ADG
Above average RFI
Not favorable phenotype



Above average ADG
Below average RFI
Favorable phenotype

Performance of Cattle with Low or High Residual Feed Intake

Cattle with low and high RFI are < 0.5 and > 0.5 SD from the mean RFI.

Trait	Low RFI	High RFI	Difference
Initial BW	=	=	0%
Final BW	=	=	0%
ADG	=	=	0%
DMI	-	+	15-20%
F:G	-	+	15-20%

Selection for Improved Feed Efficiency

Impact of Selection for Improved Residual Feed Intake on Cow Productivity

Relationship of RFI with Ultrasound Carcass Composition in Growing Bulls and Heifers

Study	REA	BF	IMF
Arthur et al., 2001a	0.06	0.14*	--
Schenkel et al., 2004	-0.10	0.17*	0.05
Lancaster et al., 2008	0.09	0.20*	0.04
Lancaster et al., 2009	-0.05	0.12*	0.08

*Phenotypic correlation coefficient is different from zero at $P < 0.05$.

Effect of Residual Feed Intake on Heifer Reproductive Traits

Heifers were measured for RFI postweaning in 2 consecutive years and data collected for the first calving season each year (Lancaster, 2008). Low RFI heifers had lower rib fat thickness at the end of the postweaning test each year.

Trait	Low RFI	High RFI	*P*-value
Cycling, %	32.1	29.6	0.80
Age at Puberty, d	279	271	0.29
1st Service Pregnancy rate, %	57.5	48.3	0.46
Pregnancy rate, %	86.8	79.7	0.50
Calving rate, %	80.7	78.3	0.95
Calving day, Julian	35	42	0.46

Effect of Residual Feed Intake on Heifer Reproductive Traits

Heifers were measured for RFI postweaning in 2 consecutive years (Shaffer et al., 2011). Heifers with low RFI had similar rib fat thickness at the end of the postweaning test.

Trait	Low RFI	High RFI	*P*-value
Age at Puberty, d	425	411	0.06
Estrus detection, %	74.4	83.3	0.59
Conception rate, %	62.1	65.7	0.89
Pregnancy rate, %	46.2	54.8	0.87

Effect of Residual Feed Intake on Heifer Reproductive Traits

Heifers were measured for RFI postweaning in 3 consecutive years and data collected for the first calving season each year (Basarab et al., 2011). Heifers with low RFI had lower rib fat thickness at the end of the postweaning test.

Trait	Low RFI	High RFI	*P*-value
Age at Puberty, d	353	347	0.36
BW at Puberty, lb	808	802	0.67
Pregnancy rate, %	76.8	86.3	0.09
Calving rate, %	72.6	84.2	0.05
Calving day, Julian	78.5	77.4	0.53

Effect of Residual Feed Intake on Heifer Reproductive Traits

Heifers were re-ranked using rib fat-adjusted RFI (Basarab et al., 2011). Rib fat thickness was similar between low and high RFI heifers.

Trait	Low RFI	High RFI	*P*-value
Age at Puberty, d	356	343	0.04
BW at Puberty, lb	819	793	0.08
Pregnancy rate, %	79.6	83.7	0.47
Calving rate, %	75.5	81.5	0.31
Calving day, Julian	77.8	77.6	0.92

Effect of Residual Feed Intake on Heifer Reproductive Traits

- Age at first calving was negatively correlated (r = -0.29) with RFI indicating that low RFI heifers conceived later in the breeding season.

Crowley et al., 2011

Effect of RFI Selection Line on Cow Reproductive Traits

Females are from low and high RFI selection lines with data from calving seasons 2000 to 2004 (Arthur et al., 2005). Cows with low RFI had lower rib fat thickness at the start of breeding season each year.

Trait	Low RFI	High RFI	*P*-value
Pregnancy rate, %	90.5	90.2	NS
Calving rate, %	89.2	88.3	NS
Weaning rate, %	81.5	80.2	NS
Calving day, Julian	215	210	0.07

Effect of Residual Feed Intake on Cow Reproductive Traits

Retrospective analysis of dams of progeny with low and high RFI with data from calving seasons 1997 to 2006 (Basarab et al., 2007). Dams of progeny with low RFI had greater rib fat thickness at pre-calving, pre-breeding, and weaning.

Trait	Low RFI	High RFI	*P*-value
Pregnancy rate, %	95.6	96.0	0.90
Calving rate, %	84.9	86.3	0.62
Weaning rate, %	81.5	82.3	0.79
Calving day, Julian	92	88	0.01
Calving interval, d	371	369	0.69

Impact of Selection on Reproduction

- Low RFI heifers may attain puberty at older age compared with high RFI heifers
  - Adjusting for differences in rib fat thickness when calculating RFI could further increase age at puberty
- Even though residual feed intake is positively related to body fat composition, cow reproductive traits were not different between low and high RFI females

Effect of Residual Feed Intake on Nursing Calf Performance

Heifers were ranked using RFI (Basarab et al., 2011). Rib fat thickness was lower in low RFI heifers.

Trait	Low RFI	High RFI	*P*-value
Birth weight, lb	81.5	79.5	0.22
ADG, lb/d	2.20	2.16	0.38
Weaning weight, lb	559	555	0.69
200-d weaning weight, lb	520	511	0.31
Lb calf weaned/ heifer exposed	399	427	0.50

Effect of RFI Selection Line on Nursing Calf Performance

Females are from low and high RFI selection lines with data from calving seasons 2000 to 2004 (Arthur et al., 2005). Cows with low RFI had lower rib fat thickness at the start of breeding season each year.

Trait	Low RFI	High RFI	*P*-value
Birth weight, lb	81.3	79.7	NS
ADG, lb/d	1.94	1.96	NS
220-d weaning weight, lb	508	508	NS
Lb calf weaned/ Cow exposed	421	436	NS

Effect of Residual Feed Intake on Nursing Calf Performance

Retrospective analysis of dams of progeny with low and high RFI with data from calving seasons 1997 to 2006 (Basarab et al., 2007). Dams of progeny with low RFI had greater rib fat thickness at pre-calving, pre-breeding, and weaning.

Trait	Low RFI	High RFI	*P*-value
Birth weight, lb	92.3	90.7	0.28
ADG, lb/d	2.29	2.33	0.58
200-d weaning weight, lb	583	591	0.70
Lb calf weaned/ lb cow BW	33.7	34.0	0.88

Impact of Selection on Calf Performance

- Cows with low RFI produced calves with similar birth weight, ADG, and weaning weight

- Based on available research, selection for low RFI cattle is not expected to impact performance of nursing calves

Impact of Selection for Improved Residual Feed Intake on Cow Efficiency

Scenario

- Selection for improved RFI
  - Selection will occur in growing yearling bulls
  - Selection will occur on high-energy concentrate based diets

- How does this translate to mature lactating cows grazing low-energy forage?

Effect of Diet on Ranking of Steers for RFI

Study	RFI in Growing vs. Finishing Cattle
Crews et al., 2003	$r_g = 0.55^*$
Brown, 2005	$r_p = 0.47^*$
Durunna et al., 2011	$r_g = 0.50^*$

Durunna et al., 2011	RFI in Growing vs. Finishing Cattle
Grower Ration	$r_p = 0.44^*$
Finisher Ration	$r_p = 0.42^*$
Grower then Finisher Ration	$r_p = 0.33^*$

Effect of Maturity on Ranking for RFI

Study	RFI in Weaner vs. Mature Cattle
Arthur et al., 2001	$r_g = 0.75^*$ $r_p = 0.43^*$
Archer et al., 2002	$r_g = 0.98^*$ $r_p = 0.40^*$

Relationship between RFI Measured as Growing Heifer and Mature Cow

Study	Mature Cow	Corr
Neiuwhof, 1992	Non-preg., lactating	0.07
Arthur, 1999	Non-preg., non-lactating	0.36*
Archer, 2002	Non-preg., non-lactating	0.40*
Herd, 2006	Non-preg., non-lactating	0.39*
Adcock, 2011	Non-preg., lactating	0.30*
Black, 2013	Non-preg., lactating	0.13
Hafla, 2013	Preg., non-lactating	0.42*

Impact of Selection for Improved RFI on Cow Efficiency

- Both diet and maturity/production stage impact the relationship between RFI in growing cattle and mature beef cows
  - Maturity/production stage seems to have the greatest influence

- Selection of low RFI in yearling growing bulls fed high-energy diets will result in minimal improvement in feed efficiency of mature lactating beef cows

Future Research

- Evaluate alternative traits to determine feed efficiency of mature cows
  - Energy Efficiency Index
    - Calculated using mathematical model of cow energy requirements

Cow Efficiency

- Maintenance energy requirements
- Milk production

- Match cow size/type and milk production with environment/forage resources
  - Most efficient cow in one environment may not be most efficient in another environment

Energy Efficiency Index

- Estimates the metabolizable energy required per pound of calf weaned
  - Desirable phenotype is the low EEI cow

- Data required
  - Cow BW and BCS at preg check
  - Cow BCS at low and high for the year
  - Calf birth and weaning weight
  - Calf birth date and weaning date
  - ME content of forage and feed throughout the year

Tedeschi et al., 2006

Energy Efficiency Index

- Advantages compared with RFI
  - Based on energy metabolism of brood cow rather than growing cattle
  - Measurement of feed intake is not required
  - Can easily be calculated with minimal data collection on the ranch
- Disadvantages compared with RFI
  - No actual measurement of feed intake
    - Cow may actually eat more than estimated

Energy Efficiency Index (EEI)

- Current assessment
  - EEI measured in 140 Santa Gertrudis cows over 4 years
    - Moderately heritable – $h^2 = 0.58$
    - Correlation among EEI across the 4 years - 0.39 to 0.56
      - Most efficient cows tended to be most efficient in each year

Item	WW EPD	Milk EPD	ADG EPD	HCW EPD	REA EPD	Marb EPD	RFI EPD
EEI yr1	-0.11	-0.26*	-0.06	-0.13	-0.13	0.15	0.02
EEI yr2	0.08	-0.42*	0.17	0.17	-0.04	0.02	-0.19
EEI yr3	-0.02	-0.46*	0.17	0.09	-0.14	0.26*	0.03
EEI yr4	-0.12	-0.45*	0.02	0.00	-0.11	0.09	-0.14

Bourg, 2011

Conclusion

- Residual feed intake is an excellent trait to select for improved feed efficiency in growing cattle that will not increase cow mature size

- Selection for low RFI:
  - May result in heifers/cows conceiving later in the breeding season
  - Will not negatively impact cow productivity

Conclusion

- Selection for low RFI in growing bulls fed high-energy diets will most likely result in minimal improvement in feed efficiency of mature lactating cows

- Energy Efficiency Index has potential for use as trait to improve feed efficiency of mature beef cows
  - Further research is needed


Questions?
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GrowSafe
GrowSafe