Impact of Selection for Feed Efficiency on Cow-Calf Production

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Introduction

Feed accounts for 60 to 70% of variable expense of beef production. The cow herd requires 72% of the energy consumed from conception to harvest (Ferrell and Jenkins, 1982), and expends the 90% of feed energy for maintenance (Johnson, 1984). Thus, significant improvement in efficiency of nutrient utilization of beef production could be realized by improving feed efficiency of the mature beef cow.

Residual feed intake (RFI), also referred to as net feed intake or net feed efficiency, is currently used as a trait to improve feed efficiency in selection programs. Koch et al. (1963) indicated that RFI is independent of growth rate and mature weight, and will not result in greater maintenance requirements of the cow herd. Residual feed intake is calculated as actual feed intake minus expected feed intake based on growth rate and body weight; animals that consume less than expected have low RFI and are more feed efficient. The use of RFI to measure feed efficiency identifies animals that consume less feed for the same growth rate and body weight.

Residual feed intake has been extensively evaluated in growing animals, but less research has evaluated RFI in mature beef cows. In the current beef production system, selection for improved RFI typically occurs in young growing bulls measured shortly after weaning in performance test stations utilizing high-energy diets. However, mature cows consume a low-energy diet and produce milk rather than deposit nutrients into tissue. This raises a significant question, what is the impact of selection for RFI in young growing bulls on performance and feed efficiency in mature cows?

Reproductive performance of heifers and cows is an important driver of profitability in the cow-calf enterprise. Body condition score or body fat is known to impact reproductive performance and pregnancy rates in beef cows; cows of low body condition with less body fat have lower pregnancy rates and longer postpartum interval. Residual feed intake is positively correlated with rib fat thickness such that more efficient cattle are leaner, which could negatively impact reproductive performance of heifers and cows (Arthur et al., 1997; Herd and Bishop, 2000; Arthur et al., 2001a; Arthur et al., 2001b; Basarab et al., 2003; Nkrumah et al., 2004; Brown, 2005; Nkrumah et al., 2007; Lancaster et al., 2009a; Lancaster et al., 2009b). Despite the relationship between RFI and body fat, previous studies (Lancaster, 2008; Basarab et al., 2011; Shaffer et al., 2011) have reported no difference in age at puberty between low and high RFI heifers, even though differences in body fat content were evident (Table 1). Additionally, Lancaster (2008) reported no difference in pregnancy, calving or weaning rate, but Basarab et al. (2011) found that low RFI heifers had lower pregnancy (77 vs. 86%) and calving rates (73 vs. 84%). Additionally, Crowley et al. (2011) found a negative genetic correlation (-0.29) between RFI and age at first calving indicating selection for improved RFI may result in heifers that conceive later in the breeding season. Basarab et al. (2011) further evaluated the relationship among RFI, body fat, and reproduction. These authors included ultrasound rib fat thickness in the calculation of RFI so that heifers with low and high RFI had the same body fat. When RFI was adjusted for rib fat thickness the difference in calving rate between low and high RFI heifers was eliminated (76 vs. 82%; $P = 0.31$), but low RFI heifers were older and heavier at puberty than high RFI heifers. These results indicate that selection for low RFI could negatively impact reproduction in heifers and that the simple solution of including rib fat thickness in the calculation of RFI may not eliminate the negative impact.

The data available on the impact of selection for low RFI on productivity of mature cows is limited to two published studies. Arthur et al. (2005) found no difference in pregnancy, calving, or weaning rate between cows from low and high RFI selection lines (Table 2). There was no difference in milk yield, calf weaning weight, or pounds of calf weaned per cow exposed between cows from low and high RFI selection lines. Basarab et al. (2007) evaluated the effect of RFI on cow productivity retrospectively by evaluating performance of dams of steers with low and high RFI; RFI was not measured on the cow. Similar to Arthur et al. (2005), these authors found no difference in pregnancy, calving, or weaning rate between dams based on RFI of their steer calves. There was no difference in calf weaning weight or pounds of calf weaned per pound of cow body weight between dams of steers with low and high RFI. These limited studies indicate that selection for low RFI will have minimal impact on cow productivity.

Several studies have compared RFI in growing heifers and again as mature cows, which is important to determine whether selection for RFI in growing cattle will improve feed efficiency of mature beef cows. Nieuwhof et al. (1992) reported a strong genetic correlation of 0.58 between RFI measured in growing heifers and again in lactating first-calf cows fed similar diets, but the phenotypic correlation was not different from zero (0.07; Table 3). Similarly, Archer et al. (2002) reported a very strong genetic correlation (0.98) between RFI measured in growing heifers and again as 3-yr old non-pregnant, non-lactating cows fed the same diet, but the phenotypic correlation of 0.40 was much lower. These results suggest that RFI measured in growing cattle and mature cows is genetically the same trait, but that expression of genetic potential may be altered due to physiological state of the animal.

Other studies have determined only the phenotypic relationship between RFI in growing heifers and mature cows (Table 3). Arthur et al. (1999) and Herd et al. (2006) found phenotypic correlations of 0.36 and 0.39 between RFI measured in growing heifers and again as 3-yr old non-pregnant, non-lactating cows fed the same diet. Hafla et al. (2013) reported a similar correlation (0.42) between RFI measured in growing heifers and again as pregnant, non-lactating first or second calf cows fed a different diet. Adcock et al. (2011) found a slightly lower correlation (0.30) when cows were non-pregnant, but lactating and fed the same diet. However, Black et al. (2013) reported no significant relationship (0.13) between RFI measured in growing heifers and again as 3-yr old non-pregnant, lactating cows fed a different diet. Collectively, these results suggest that different physiological state (growing versus pregnant or lactating) can drastically reduce the relationship with feed efficiency of growing cattle, which indicates that selection for low RFI in young growing bulls fed high-energy diets will most likely result in minimal improvement in feed efficiency of mature lactating cows.

The reason for the low correlation between RFI of growing cattle with RFI of mature cows is most likely due to differences in nutrient metabolism. Nutrient metabolism of the mature cow is complex. Nutrients from feed are used for lactation and conceptus growth, as well as body fat and muscle reserves. The cow must have the ability to mobilize nutrients from body reserves to produce milk early in lactation, then shift nutrients toward conceptus growth and rebuilding body reserves later in the production cycle. Thus, the efficient cow must have the ability to efficiently produce milk in the mammary gland, transport nutrients across the placenta, and synthesize and breakdown lipids and protein in fat and muscle. Moreover, she must do all this with the feed resources available. Ferrell and Jenkins (1985) indicated that the most efficient cows in one nutritional environment are not necessarily the most efficient cows in another nutritional environment. For example, a cow with genetic ability for high milk production will be highly efficient when high-quality forage is available, but will struggle to maintain body condition and rebreed when only low-quality forage is available. Thus, to identify efficient mature cows, feed intake, changes in body weight, and milk production would have to be measured during multiple stages of the production cycle (e.g. early lactation, late lactation, late gestation) under the ranch conditions in which the cow will have to perform. This would require enormous cost to ranchers that would probably outweigh the benefits of selection for improved RFI.

Recently, Tedeschi et al. (2006) developed a model to calculate an energy efficiency index (EEI) for beef cows based on body condition score and body weight of cows, weaning weight of calves, and forage nutritive value. The amount of metabolizable energy required per pound of weaned calf, which is EEI, can be calculated for each cow in the herd. The use of EEI to evaluate efficiency of mature cows has some advantages compared with RFI. First, this calculation does not require measurement of feed intake making it less difficult to evaluate efficiency of mature beef cows and allowing evaluation on pasture at the ranch. Additionally, the calculation is based on energy metabolism of the mature cow taking into account lactation, conceptus growth, and body reserves rather than energy metabolism of growing animals as with RFI. However, one potential disadvantage is that estimating the metabolizable energy required rather than actually measuring feed intake may lead to erroneous classification of efficient and inefficient cows.

Currently, only 1 study has evaluated EEI in 140 Santa Gertrudis cows over 4 production cycles (Bourg, 2011). In this study, EEI was positively correlated (0.39 to 0.56) across production cycles indicating that efficient cows in one year were likely to be efficient in subsequent years. Additionally, EEI had a heritability of 0.58 in this study indicating that selection could be used to improve EEI of mature cows. This estimate of heritability is greater than estimates for RFI, and is similar to heritability of mature cow weight and yearling hip height (Koots et al., 1994). Bourg (2011) found that EEI was negatively correlated with milk expected progeny difference (EPD) of cows indicating that the most efficient cows produced more milk (Table 4). However, EEI was not correlated with weaning weight EPD, average daily gain EPD, hot carcass weight EPD, ribeye area EPD, marbling EPD, or residual feed intake EPD. These results suggest that more efficient cows could be selected based on EEI without correlated responses in growth, body weight, or carcass merit of offspring. Energy efficiency index was not related to RFI EPD, which suggests that these traits are not measuring the same biological processes and supports the idea that RFI measured in growing animals does not translate to improved energy metabolism and efficiency of mature beef cows.

Conclusions

Residual feed intake is a measure of feed efficiency that is independent of growth rate and mature body weight indicating that selection for improved residual feed intake would not negatively impact mature cow size and maintenance requirements of the cow herd. Limited research indicates that selection for improved residual feed intake would have minimal impact on cow productivity. However, residual feed intake is weakly correlated with body fat content such that more efficient cattle are leaner. Additionally, more efficient heifers as measured by residual feed intake may achieve puberty at older age and conceive later in the breeding season, which may be related to differences in body fat content. Additional research is needed to better understand the relationship of residual feed intake with female reproductive performance.

Several studies have reported a weak relationship between residual feed intake measured in growing cattle and again as mature cows. This suggests that even though selection for residual feed intake will not impact cow productivity, it likely will not result in much improvement in feed efficiency of the mature cow either. This is most likely due to the differences in energy metabolism between growing cattle and mature lactating cows. Energy efficiency index is based on energy metabolism of mature beef cows and allows evaluation of the beef cow in her production environment. Very little data is available evaluating energy efficiency index in beef cows, but energy efficiency index shows potential as a trait to identify efficient beef cows.

Table 1. Reproductive performance of beef heifers with low and high residual feed intake

	Lancaster, 2008		Shaffer et al., 2011		Basarab et al., 2011	
Trait	Low RFI	High RFI	Low RFI	High RFI	Low RFI	High RFI
Age at puberty, d	279	271	425	411	353	347
Pregnancy rate, %	89	79	62	66	77[a]	86[b]
Calving rate, %	81	78			73[a]	84[b]

[ab]Means within a row and study with different superscripts differ ($P < 0.10$).

Table 2. Reproductive performance and productivity of mature beef cows with low and high residual feed intake

	Arthur et al., 2005		Basarab et al., 2007	
Trait	Low RFI	High RFI	Low RFI	High RFI
Pregnancy rate, %	90.5	90.2	95.6	96.0
Calving rate, %	89.2	88.3	84.9	86.3
Weaning rate, %	81.5	80.2	81.5	82.3
Milk yield, lb/d	16.5	17.2	--	--
Age-adjusted weaning weight, lb	508	508	583	591
Weight of calf weaned per pound of cow weight, lb/lb	--	--	0.337	0.340
Weight of calf weaned per cow exposed, lb	421	437	--	--

Table 3. Relationships of residual feed intake measured in growing and mature cattle

	Cattle Description		
Study	Age 1	Age 2	r_p[1]
Nieuwhof et al., 1992	Growing dairy heifer	Non-pregnant, lactating 1st-calf cow fed similar diet	0.07
Arthur et al., 1999	Growing heifer	Non-pregnant, non-lactating cow fed same diet	0.36*
Archer et al., 2002	Growing heifer	Non-pregnant, non-lactating cow fed same diet	0.40*
Herd et al., 2006	Growing heifer	Non-pregnant, non-lactating cow fed same diet	0.39*
Adcock et al., 2011	Growing heifer	Non-pregnant, lactating cow fed same diet	0.30*
Black et al., 2013	Growing heifer	Non-pregnant, lactating cow fed different diet	0.13
Hafla et al., 2013	Growing heifer	Pregnant, non-lactating 1st or 2nd-calf cow fed different diet	0.42*

[1]r_p = phenotypic correlation coefficient.
*Correlation coefficient is different from zero ($P < 0.05$).

Table 4. Relationships between energy efficiency index (EEI) and expected progeny differences (EPD) of Santa Gertrudis cows across 4 production cycles

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

WW = weaning weight; ADG = postweaning average daily gain; HCW = hot carcass weight; REA = ribeye area; Marb = marbling score; RFI = residual feed intake.
*Correlation is different from zero ($P < 0.05$).

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