ABSTRACT: Although feed intake and efficiency differences in growing cattle of low and high residual feed intake (RFI) classification have been established, little is known about the difference in grazed forage intake between beef cows of known RFI classification. Two experiments were conducted using Hereford cows for which RFI had been determined as heifers using the GrowSafe 4000E feed intake system, after which heifers had been divided into thirds as low RFI, mid RFI, and high RFI. During Exp. 1, 2 replicates of low and high RFI cows (n = 7/replicate) in mid- to late-gestation were blocked to 1 of 4 non-endophyte-infected tall fescue paddocks (1.8 to 2.4 ha), which they grazed continuously for 84 d during summer. Using grazing exclosures, weekly rising plate meter readings, and forage harvests every 21 d, average forage DMI was calculated. Low and high RFI groups did not differ (P > 0.05) in BW change or BCS change over the trial (19.5 vs. 22.1 kg of BW gain and 0.11 vs. 0.10 BCS gain), but low RFI cows had a 21% numerically lower DMI than high RFI cows (12.4 vs. 15.6 kg/d; P = 0.23). The average area needed per paddock over the trial was similar for low and high RFI cows (1.71 vs. 1.82 ha; P = 0.35), and the average DM on offer over the trial was less for low RFI than for high RFI cows (4,215 vs. 4,376 kg; P = 0.06). During Exp. 2, 3 replicates of low and high RFI cows with their calves (n = 4 pair/replicate) strip-grazed stockpiled and early spring growth tall fescue paddocks (0.7 to 0.9 ha) for 60 d in late winter and early spring. Because of limiting forage availability and quality at trial initiation, cow-calf pairs were also fed 3.31 kg/pair of pelleted soyhulls daily. Pre- and post-grazed forage samples were harvested for 4 grazing periods, and forage growth was estimated using a growing degree days calculation and on-site weather station data. Performance did not differ (P > 0.05) between low and high RFI cows throughout the experiment (18.4 vs. 26.6 kg of BW gain and −0.04 vs. 0.15 BCS gain). Despite the utilization of forage offered being similar for low and high RFI cow-calf pairs (P > 0.05), low RFI cows and their calves had an 11% numerically lower DMI than high RFI pairs (12.5 vs. 14.1 kg/d; P = 0.12). We concluded that either no intake differences existed between low and high RFI cows or that current methodology and small animal numbers limited our ability to detect differences.

Key words: beef cow, feed efficiency, forage intake, residual feed intake

INTRODUCTION

Providing adequate nutrition for their animals is the greatest operating cost for cow-calf producers. The USDA Economic Research Service estimated that in 2004 and 2005 feed-associated costs made up 59.2 and 55.7%, respectively, of all nonfixed costs of US cow-calf operations (USDA-ERS, 2005). Traditionally, more selection emphasis in the beef industry has focused upon increasing outputs, which can often increase inputs as well. Because feed makes up such a great portion of total inputs, any reduction in feed intake while maintaining production could have a great impact upon profitability of cow-calf operations.

One means to reduce feed inputs is through improvement in feed efficiency. It has been well established that individual differences for this trait exist in beef cattle, making selection possible. Although feed conversion ratio (F:G) or gross efficiency (G:F) are often used, residual feed intake (RFI) may be a more accurate representation of the actual genetic and biological differences in feed efficiency (Archer et al., 1999). Residual feed intake is calculated as the difference between an animal’s actual measured intake and its predicted intake based on its growth rate and BW. This makes RFI a moderately heritable trait (Arthur et al., 2001b), phenotypically independent of growth and body size, unlike F:G or G:F.
Feed intake has been shown to be less in growing cattle that were determined to have low RFI classification (high efficiency) or were from herds divergently selected for low RFI, but little is known of the difference in grazed forage intake of mature cows in relation to RFI or selection for this trait (Herd et al., 2003). We hypothesized that cows of low RFI classification would consume less forage DM than their high RFI counterparts, while still maintaining similar BW and condition. Therefore, the objective of this research was to determine the effect of RFI classification on the grazed forage intake of beef cows and the subsequent pasture carrying capacity.

MATERIALS AND METHODS

Use of animals in these experiments was approved by the University of Missouri Animal Care and Use Committee.

Determination of RFI

During the summer of 2005, a 51-d trial was conducted using 42 Hereford heifers (average initial BW = 491 ± 20 kg, average initial age = 1.9 ± 0.1 yr) for which RFI were determined using the GrowSafe feed intake system (model 4000E, GrowSafe Systems Ltd., Airdrie, AB, Canada). Heifers were randomly allocated to 8 pens (5 to 6 heifers/pen, 7.3 x 16.5 m) each with 2 GrowSafe bunks. After an acclimation period, heifers were given ad libitum access to water and unprocessed flakes of square-baled alfalfa-grass mixed hay (13.7% CP, 58.6% NDF, 39.2% ADF, 55% TDN; DM basis) for the duration of the feeding trial. Hay fed met or exceeded nutrient requirements for heifers of this age and production stage (NRC, 2000). Two consecutive day BW were then used to calculate metabolic midweight and trial ADG. Individual daily hay intakes were recorded by the GrowSafe system, and the RFI was calculated for the duration of the feeding trial. Hay fed was defined as the amount of feed consumed by the heifers in the trial.

Experiment 1

Experimental Design. An 84-d grazing trial was conducted from May 18 to August 9, 2006, at the University of Missouri South Farm to determine the grazed forage intake of beef cows of known RFI classification. Purebred Hereford cows (n = 28, average initial BW = 578.1 ± 1.2 kg, average initial BCS = 5.26 ± 0.07) from the low RFI (highly efficient) and high RFI (lowly efficient) groups previously determined were used after their first calving season. Fifteen of these cows had calved during the previous fall (7 low RFI, 8 high RFI), whereas the remainder had not yet calved due to young age or not conceiving during the breeding season. All animals will be referred to as “cows” for this and the subsequent experiment because all animals were over 2 yr of age (date of birth: February 26, 2001, to February 20, 2004) when both experiments were conducted, even if they had not calved before Exp. 1. Twenty-four cows were verified pregnant by rectal palpation pretrial, with expected calving dates ranging from September 1 to November 15, 2006. All but 4 cows were thus in mid- to late-gestation and were not lactating during this experiment.

Low and high RFI groups were allocated by BW, BCS, RFI, cow age, pregnancy status, and estimated calving date to 2 replicates each (n = 7). These cows were then blocked by pasture and allocated to graze 4 paddocks (1.8 to 2.4 ha/paddock) created from 2 non-endophyte-infected tall fescue-based pastures. Paddocks were grazed continuously throughout the trial and cows had ad libitum access to water and a commercial mineral and vitamin supplement (13% Ca, 6.5% P, 18% NaCl, 1.4% Mg, 0.8% K, 1,250 mg/kg of Mn, 650 mg/kg of Cu, 30 mg/kg of Co, 69 mg/kg of I, 23 mg/kg of Se, 2,188 mg/kg of Zn, 330,000 IU/kg of vitamin A, 33,000 IU/kg of vitamin D3, 330 IU/kg of vitamin E; Purina Mills, LLC, St. Louis, MO). The mineral supplement fed contained lasalocid (1.58 g/kg as lasalocid sodium) due to known performance benefits for growing cattle, as the majority of animals used in this study were not yet at mature weight.

To keep forage availability similar between paddocks, electric poly-tape and movable step-in posts were used to create a buffer area. This was adjusted in size as needed by using weekly electronic rising plate meter (RPM; FarmWorks, Feilding, New Zealand) readings to compute total RPM units/paddock. Rising plate meter units served as estimates of forage DM on a given sampling date. Total RPM units per paddock were computed to compare forage yield between paddocks in each replicate. This measure was corrected for paddock size by using the equation: RPM × Areapaddock. Paddocks were then adjusted in size to keep total RPM units within 10 per paddock for replicates from each pasture (block).

Forage Yield and Quality Measurement. To measure forage growth, each paddock had 10 exclosures made from round bale feeders (198-cm diameter) surrounded by wire fence. Every 21 d, the exclosures were sampled by taking a cross-section at right angles with a tractor-powered flail-type harvester (81.3 cm wide,
forage cut to a 2-cm height). Cross-section lengths were measured and recorded for use in calculating the area sampled. After sampling, each exclosure was moved to a new location within the paddock to determine growth during the next sampling period. Coinciding with exclosure sampling, the grazed areas of the paddocks were also sampled to determine forage DM on offer by harvesting 10 strips (4.9 m × 81.3 cm each, forage cut to a 2-cm height) from each paddock.

Forage obtained from each cross-section (exclosure) and strip from the grazed area was weighed and subsampled in the field. Subsamples were then weighed, dried at 55°C for 48 h, and ground to 1 mm using a Wiley mill (Thomas Scientific, Swedesboro, NJ) and a Cyclotec grinder (model 1093, Tecator AB, Höganas, Sweden). Ground forage samples were dried at 100°C for 24 h to determine total DM and ashed at 600°C for 12 h to determine ash content (AOAC, 1984). Neutral detergent fiber and ADF were sequentially analyzed using an Ankom Fiber Analyzer (model 200, Ankom, Fairport, NY). A Leco N analyzer (model FP-428, Leco, St. Joseph, MI) was used to determine N content by thermoconductivity, which was then used to calculate CP (N × 6.25).

Temperature and precipitation data during the experiment were collected from a weather station located on the research farm, and 30-yr average data were obtained from the National Oceanic and Atmospheric Administration’s National Weather Service archive of climatology and weather records for Columbia, Missouri.

Animal Performance Measurements. Two-day consecutive BW were taken at the beginning and end of the study. Cows were also weighed on d 21, 42, and 63, although d 42 BW were not used because of a scale malfunction. All BW were taken in early morning without removal from feed or water. Additionally, cows were body condition scored (1 to 9 scale, 1 = emaciated, 9 = obese) by 3 trained technicians on d 0, 42, and 84. These 3 scores were averaged by date for each cow for use in subsequent data analysis.

Statistical Analysis. Weekly RPM readings and date of experiment were used in a stepwise model selection using the REG procedure (SAS Inst. Inc., Cary, NC) to predict forage DM yield of the grazed area. Predicted DM yield was then used with actual DM yield taken from exclosure sampling to calculate the total DMI per paddock per 21-d period as: DMIPaddock = AreaGrazed × [(YieldExclosuret1 − YieldGrazedt0) − (YieldGrazedt1 − YieldGrazedt0)], where t0 = the previous sampling and t1 = the current sampling. This was then used to calculate average individual DMI (kg/d) for each period.

Performance, intake, and forage yield and quality data were analyzed as a randomized complete block design using the GLM procedure (SAS Inst. Inc.) with paddock as the experimental unit and pasture as the block. Means were determined using the least squares means statement of SAS and were separated by Fisher’s LSD. Orthogonal contrasts were used to determine the linear, quadratic, and cubic effects of sampling date on forage yield and quality. Means were considered different if P ≤ 0.10.

Experiment 2

Experimental Design. A second 60-d grazing trial was conducted from February 23 to April 23, 2007, at the University of Missouri South Farm to determine the forage intake of lactating beef cows of known RFI classification: grazing stockpiled and spring-growth tall fescue. Purebred Hereford cows (n = 24, average initial BW = 563 ± 10.5 kg, average initial BCS = 4.92 ± 0.14) from the low RFI (highly efficient) and high RFI (lowly efficient) groups with calves at side (n = 24, average initial BW = 136 ± 6.0 kg, average initial age = 143 ± 7.0 d) were used. Cows from each group were allocated with their calves by BW, BCS, RFI, cow age, and calf age to 3 replicates. Calves at side were the result of random mating with respect to RFI because they were sired by bulls of unknown RFI status.

Animal and Paddock Management. Twelve tall fescue-based paddocks (6 low-endophyte-infected, 6 high-endophyte-infected; 0.73 to 0.93 ha/paddock) were used for this experiment. In mid-August 2006, 45 kg of N/ha was applied to the paddocks used in this study, which had been previously grazed or mowed to a 10-cm stubble height. After N application, forage was allowed to accumulate until trial initiation (February 23). The original experimental design was to begin the grazing trial earlier to avoid spring growth. However, because of an unusual amount of snow and ice accumulation during the winter, this was not possible.

Paddocks were strip-grazed using electric poly-tape and movable step-in posts, and a new strip was allocated every 3.5 d (2×/wk). Initial strip allocations were determined using a set residual and assuming that cow-calf pairs would consume 1.2% of their BW in NDF daily (Mertens, 1987). After this, strip size was allocated based upon the residual left after grazing the previous strip. The goal of strip allocation was to not limit intake while keeping utilization similar between paddocks. Strip size was calculated based on the number of days expected for grazing each allocation when a 3.5-d moving schedule could not be kept. When strips were grazed more quickly than anticipated, new strips were given earlier than planned so that forage availability was not limiting for more than 12 h.

The trial was divided into 4 grazing periods (period 1: d 1 to 18, period 2: d 19 to 37, period 3: d 38 to 47, period 4: d 48 to 60). During periods 1 and 2, all replicates except one (a low RFI replicate that had to be moved due to limited forage availability after period 1) grazed low-endophyte-infected paddocks. High-endophyte-infected paddocks were then grazed during periods 3 and 4.

Forage quality and availability were limiting at trial initiation; therefore, to maintain body condition of
Table 1. Performance of cows with low and high residual feed intake (RFI) during Exp. 1 and 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low RFI</th>
<th>High RFI</th>
<th>SEM¹</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. 1 cows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFI, kg/d</td>
<td>−4.37</td>
<td>5.04</td>
<td>0.70</td>
<td>0.006</td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>591.2</td>
<td>565.0</td>
<td>1.2</td>
<td>0.004</td>
</tr>
<tr>
<td>Initial BCS²</td>
<td>5.26</td>
<td>5.26</td>
<td>0.07</td>
<td>1.00</td>
</tr>
<tr>
<td>BW change, kg</td>
<td>19.5</td>
<td>22.1</td>
<td>3.4</td>
<td>0.68</td>
</tr>
<tr>
<td>BCS change</td>
<td>0.11</td>
<td>0.10</td>
<td>0.05</td>
<td>0.86</td>
</tr>
<tr>
<td>Exp. 2 cows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFI, kg/d</td>
<td>−4.22</td>
<td>5.13</td>
<td>0.26</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>569.4</td>
<td>557.2</td>
<td>10.5</td>
<td>0.46</td>
</tr>
<tr>
<td>Initial BCS²</td>
<td>4.85</td>
<td>4.98</td>
<td>0.14</td>
<td>0.55</td>
</tr>
<tr>
<td>BW change, kg</td>
<td>18.4</td>
<td>26.6</td>
<td>10.0</td>
<td>0.59</td>
</tr>
<tr>
<td>BCS change</td>
<td>−0.04</td>
<td>0.15</td>
<td>0.08</td>
<td>0.19</td>
</tr>
<tr>
<td>Exp. 2 calves</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, d</td>
<td>144</td>
<td>143</td>
<td>7</td>
<td>0.87</td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>140.7</td>
<td>131.5</td>
<td>6.0</td>
<td>0.34</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>0.85</td>
<td>0.95</td>
<td>0.08</td>
<td>0.45</td>
</tr>
</tbody>
</table>

¹For n = 2 in Exp. 1 (2 replicate paddocks of 7 cows for each RFI group) and n = 3 in Exp. 2 (3 replicate paddocks of 4 cow-calf pairs for each RFI group).
²RFI were determined for these animals as heifers, while fed a hay diet.
³BCS evaluated on 1 to 9 scale (1 = emaciated, 9 = obese).

cows, cow-calf pairs were supplemented daily with 3.31 kg of pelleted soyhulls (9.6% CP, DM basis), regardless of RFI classification. Pairs had adequate bunk space and ad libitum access to water and the same commercial mineral and vitamin supplement containing lasalocid as in Exp. 1.

Forage Yield and Quality Measurement. Forage was sampled 5 times throughout the trial (d −13, 18, 32, 47, and 60) so that pregrazing samples were harvested before and postgrazing samples were taken after each grazing period. Postgrazing samples were harvested from the strips allocated since the previous sampling, and pregrazing samples were taken from the area estimated to be allocated before the following sampling date. Sampling dates, and thus exact period lengths, were changed as necessary when precipitation prevented forage harvest, resulting in periods of unequal length. On 2 dates (d 32 and 47), sampling was interrupted by rain after some paddocks had been harvested and the remaining paddocks were sampled as soon as weather and soil conditions allowed (d 33 and 49, respectively).

Pre- and postgrazed forage was sampled in the same way as the grazed area in Exp. 1, with 10 strips (4.6 m × 81.3 cm each, forage cut down to 2 cm forage height) harvested per paddock. Subsamples were dried, ground, and analyzed for DM, ash, NDF, ADF, and CP as in Exp. 1.

Temperature and precipitation data during the experiment were again collected from the weather station located on the research farm, and 30-yr average data were obtained from National Oceanic and Atmospheric Administration’s National Weather Service archive of climatology and weather records for Columbia, Missouri.

Animal Performance Measurements. At the trial’s initiation and conclusion, cows and calves were weighed on 2 consecutive days and cows were body condition scored by 2 trained technicians. Cows and calves were also weighed on d 29. All BW were taken without removal from feed and water, and BCS were averaged per cow and date for use in later analysis.

Statistical Analysis. Forage growth within a period (GrowthCalc) was estimated using growing degree days (base 4.4°C for tall fescue) using the temperature data previously collected. The total forage DMI per paddock for each period was calculated by: DMIPaddock = AreaGrazed × [(YieldPregrazed + GrowthCalc) − YieldPostgrazed]. This was then used to determine average forage DMI per pair (kg/d).

The data were analyzed as a completely randomized design with paddock as the experimental unit and RFI group as the fixed effect in the GLM procedure (SAS Inst. Inc.). Means were determined using the least squares means statement of SAS and were separated by Fisher’s LSD and were considered different if P ≤ 0.10.

RESULTS AND DISCUSSION

Heifer RFI

Residual feed intakes of animals in this study, when determined as heifers, ranged from −9.21 to 10.26 kg/d (data not shown). Average RFI for low and high groups used in Exp. 1 and 2 are shown in Table 1. During RFI determination, no differences were observed among RFI groups for initial BW. Average daily gain through RFI determination was 0.59 kg/d and also did not differ between low and high RFI groups.

The range of RFI reported here is greater than that typically reported for a group of growing cattle that are not the result of divergent selection for and against feed efficiency (Nkrumah et al., 2004; Kolath et al., 2006; Castro Bulle et al., 2007), but may be attributed to a variety of factors. One major difference is that RFI in the cited studies were determined on a pelleted ration. Although some rations used to determine RFI have been pelleted but with increased forage content (Arthur et al., 1999), to the authors’ knowledge no other experiments have been published in which RFI has been determined using hay without grinding and pelleting. Because the heifers would be consuming a forage-based diet as cows, unprocessed hay was chosen to determine postweaning RFI in this study. The GrowSafe system is intended for pelleted or grain-based rations, and thus using it to feed hay most likely introduced error due to heifers wasting hay that was removed from the feeder but not consumed. This should not have seriously affected RFI rank, however, because heifers consuming more hay probably had more eating...
bouts at the bunk (Golden et al., 2008), and probably wasted more forage.

**Animal Performance**

Cow performance for Exp. 1 and 2 is shown in Table 1. Although there was no difference in initial BCS between RFI groups in Exp. 1 ($P = 1.00$), low RFI cows were heavier at trial initiation than high RFI cows ($P = 0.004$). There were no differences between low and high RFI cows for BW change ($P = 0.68$) or BCS change ($P = 0.86$) throughout the trial, and both groups gained weight and condition as the trial progressed.

When low and high RFI cows began Exp. 2, they had similar initial BW ($P = 0.46$) and BCS ($P = 0.55$). In addition, there were no differences between RFI groups for cow BW change ($P = 0.59$) or BCS change ($P = 0.19$) throughout the experiment. There were no differences in calf age ($P = 0.87$), initial calf BW ($P = 0.34$), or calf ADG in Exp. 2 ($P = 0.45$) in relation to RFI group of dam.

Because cows were managed together before both experiments, the difference in initial cow BW (Exp. 1) and lack thereof (RFI determination and Exp. 2) could either be true biologically or simply a result of the small numbers and varied genetics of the animals used in this study. Using cows for which RFI had been determined postweaning, Herd et al. (1998) found that low RFI cows were significantly heavier than their high RFI counterparts in a pasture intake trial. In another study examining the effect of selection for RFI upon maternal productivity over 4 yr, low RFI line cows were numerically heavier at all time points, but this difference was not significant (Arthur et al., 2005). This is in contrast to a study in which there was no difference in mature cow BW between RFI groups that had been determined postweaning when their RFI were redetermined as 4 yr olds (Arthur et al., 1999). Recent mouse research conducted by Hughes and Pitchford (2004) agreed and found no differences in dam or dam plus litter mid-weight during gestation and lactation. Genetic correlations between postweaning RFI and mature weight have been found to be between $-0.09 \pm 0.26$ and $-0.22$ (Herd and Bishop, 2000; Archer et al., 2002). These correlations indicate that although RFI is by definition not correlated to BW, selection for low RFI may cause an increase in mature cow size due to a low negative genetic correlation between the 2 traits, which may explain differences observed in BW in Exp. 1.

Cattle of differing RFI classification are known to have similar performance, as shown in this study. Arthur and coworkers have reported that for both cows with RFI determined postweaning (Arthur et al., 1999) and cows from lines divergently selected for RFI (Arthur et al., 2005), low and high RFI cows had similar ADG and BW change, respectively. Similarly, mice from low and high RFI lines have been shown to have similar dam and dam plus litter ADG during gestation and lactation (Hughes and Pitchford, 2004). Growing

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**Table 2.** Average forage yield and quality by sampling date and residual feed intake (RFI) group during Exp. 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Sampling date, $P = $</th>
<th>$d_{42}$</th>
<th>$d_{63}$</th>
<th>$d_{84}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM yield, kg/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low RFI</td>
<td>2.587</td>
<td>2.537</td>
<td>2.442</td>
<td>2.442</td>
</tr>
<tr>
<td>High RFI</td>
<td>2.562</td>
<td>2.545</td>
<td>2.456</td>
<td>2.456</td>
</tr>
<tr>
<td>CP, % of DM</td>
<td>7.2</td>
<td>7.2</td>
<td>7.2</td>
<td>7.2</td>
</tr>
<tr>
<td>NDF, % of DM</td>
<td>67.8</td>
<td>67.9</td>
<td>68.0</td>
<td>68.0</td>
</tr>
<tr>
<td>ADF, % of DM</td>
<td>39.1</td>
<td>39.3</td>
<td>41.6</td>
<td>41.6</td>
</tr>
</tbody>
</table>

1 $d_{21} =$ June 8; $d_{42} =$ June 28; $d_{63} =$ July 29; $d_{84} =$ August 10.

2 For $n = 2$ paddocks for each RFI group.

3 $L =$ linear, $Q =$ quadratic, $C =$ cubic.

4 Yield calculated by regression equation derived from rising plate meter readings and harvested yield data.
steers either determined to have low and high RFI (Basarab et al., 2003; Kolath et al., 2006; Castro Bulle et al., 2007) or from lines divergently selected for RFI (Arthur et al., 2001a) have also exhibited no difference in ADG. The genetic correlation of postweaning RFI to postweaning ADG has been reported to be −0.06 (Ar

Because it has been established that cattle from low and high RFI classification or lines have similar growth potential postweaning, and that milk yield, when determined by the weigh-suckle-weigh method, has been shown to be similar between cows of low and high RFI classification (Arthur et al., 1999) and divergently selected RFI lines (Arthur et al., 2005), observed preweaning calf performance was as expected in Exp. 2. In support of the current data, Herd et al. (1998) and Arthur et al. (2005) found that calves from low and high RFI dams had similar weaning weights and preweaning ADG.

Forage Yield and Quality

Average forage yield and quality by RFI group and sampling date for Exp. 1 are shown in Table 2. Although there was an effect of sampling date (P < 0.05) for all yield and quality measures, there was no effect of RFI group or RFI group × sampling date for DM yield, CP, NDF, and ADF. As expected, forage yield decreased (linear P < 0.001, quadratic P < 0.001, cubic P = 0.03) as the experiment and summer progressed, following the normal growth curve of a cool-season grass. As growth decreased and cattle grazed more selectively, CP decreased (linear P = 0.003, quadratic P = 0.007) and NDF and ADF increased (NDF: linear P < 0.001, quadratic P = 0.004; ADF: linear P < 0.001, quadratic P = 0.02). Although temperatures were near the 30-yr average during Exp. 1, precipitation during May and July was considerably less than the average (Figure 1). This lower rainfall likely decreased forage yield potential during this experiment.

Table 3 shows the average forage yield and quality by sampling date and RFI group for Exp. 2. There was no effect of RFI group or RFI group × sampling date for DM yield, CP, NDF, or ADF. Although DM yield did not differ among sampling dates, sampling date affected CP, NDF, and ADF (P ≤ 0.10). Temperature and precipitation data from stockpile initiation through the grazing trial of Exp. 2 are shown versus the 30-yr average in Figure 1. Less than average rainfall in September and November likely limited the initial stockpiled forage yield. When the weather data were averaged for the 4 grazing periods (Table 4), warmer temperatures were seen in period 2, followed by cooler temperatures in period 3, and warmer temperatures in period 4. The warming trend during period 2 probably aided beginning forage growth. Growth was then likely stunted by the cooler temperatures in period 3, and resumed during the warmer conditions of period 4. The CP increased (linear P = 0.02, cubic P = 0.07) and NDF and ADF decreased (NDF: linear P = 0.004, quadratic P = 0.01; ADF: linear P = 0.06, quadratic P = 0.09) after forage growth began and diluted the poorer quality stockpile.
Forage Intake

Grazed forage intake and pasture carrying capacity data from Exp. 1 and 2 are shown in Table 5. No differences were observed in DMI between low and high RFI cows; however, low RFI cows had a 21% numerically lower average DMI than high RFI cows (12.4 vs. 15.6 ± 0.9 kg/d; \( P = 0.23 \)). As a measure of pasture carrying capacity, the average area per paddock needed to maintain cows over the trial was similar between low and high RFI cows (1.71 vs. 1.82 ± 0.05 ha; \( P = 0.35 \)). The DM on offer, averaged per paddock throughout the trial, was less for low RFI than for high RFI cows (4,215 vs. 4,376 ± 11 kg; \( P = 0.06 \)), even though both maintained similar BW, BCS, and DM yield (kg/ha) over the course of the trial.

In Exp. 2, no differences were observed in DMI, although low RFI cow-calf pairs had an 11% numerically lower DMI on average than high RFI pairs (12.5 vs. 14.1 ± 0.7 kg/d; \( P = 0.12 \)). There was no difference in forage utilization throughout the trial (75.5 vs. 76.3 ± 2.5%; \( P = 0.84 \)), however, per experimental design.

Because of the difficulty in measuring grazed forage intake, there is little previous published research with which to compare these results. In a similar trial, Herd et al. (1998) found a small numerical difference in forage intake and a 15% increase \(( P = 0.07 \)) in calf BW/cow DMI between low and high RFI lactating cows on pasture. Another study, in which nonlactating, open cows for which RFI had been determined postweaning consumed a pelleted hay-wheat ration, found that low RFI line cows had a significant 4.5% lower DMI compared with their high RFI line counterparts (Arthur et al., 1999). This research helped to determine the correlation between RFI determined postweaning and at maturity, because RFI remained different between low and high RFI cows when measured at 4 to 4.5 yr of age. The phenotypic correlation of postweaning RFI to cow RFI has been reported between 0.36 and 0.40, whereas the genetic correlation has been shown to be stronger at 0.98 (Arthur et al., 1999; Archer et al., 2002).

In steers fed a concentrate-based diet, the DMI of low RFI steers has been documented to be between 12 and 17% less than that of high RFI steers (Nkrumah et al., 2004, 2006; Kolath et al., 2006; Castro Bulle et al., 2007). A 6% difference in DMI was observed after 1 generation of divergent selection for RFI (Richardson et al., 1998) compared with an 11% difference after 5 yr of divergent selection (Arthur et al., 2001a).

Although differences in intake of low- and high-RFI growing animals fed concentrate diets have been consistently reported, the current study and previous work have observed similar forage intakes for cows (Herd et al., 1998) and only small differences for cows consuming a pelleted ration (Arthur et al., 1999). There are two possible explanations for the similar intakes observed: 1) no differences existed in grazed forage intake between low and high RFI cows, or 2) current methodology is not precise enough or numbers of animals and
experimental units (paddocks) were not adequate to detect differences in grazed forage intake between low and high RFI cows.

Similar grazed forage intakes observed between low and high RFI cows may be due to changes in feed efficiency caused by physiologically induced differences in requirements due to maintenance, gestation, and lactation. These processes may affect RFI differently than growth, the stage in which intake differences of low and high RFI cattle have been observed. Hughes and Pitchford (2004) studied the difference in intake and RFI during pre-pregnancy (maintenance), gestation, and lactation between lines of female mice after 9 to 10 generations of selection for low or high RFI. Before the animals were pregnant, there was a significant difference of about 20% in DMI and RFI. The difference in DMI decreased slightly during gestation, during which the difference in RFI lessened to 12%. During early lactation, the DMI difference diminished and RFI for the 2 lines converged. Although RFI redidverged in late lactation, intakes remained similar between the 2 lines. These authors suggested that when mice were at maintenance requirements alone, the low RFI line had the advantage in efficiency, but when requirements increased due to BW gain and milk production during gestation and lactation, they became less efficient. They hypothesized that high RFI line mice were able to repartition previously wasted intake to fetal growth and milk production, whereas the low RFI line individuals did not have this buffer and thus had to increase intake.

In the current study, cows in Exp. 2 were in late lactation during the grazing period; therefore, if RFI phenotypes do converge during early lactation, this period was missed. The intakes observed for cows during gestation in Exp. 1 and during lactation in Exp. 2 may be due in part to these different production periods and the associated efficiencies of the physiological processes.

A study conducted by Herd et al. (2002) with stocker steers resulting from 1 generation of divergent selection for RFI found that low RFI steers consumed numerically 10% less forage, had improved ($P = 0.10$) ADG, and had 25% numerically better F:G. No forage quality data were presented for this study, and thus it is possible that intake was limited because of fiber content, which then decreased the DMI difference observed and forced a difference in ADG. However, similar intakes were observed between low and high RFI line steers, and because data from growing steers fed concentrate diets show intake differences, efficiency may be affected differently by forages than by concentrate-based diets.

### Table 4. Total precipitation and average temperatures during grazing periods of Exp. 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Grazing period</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total precipitation, cm</td>
<td>Feb 23 to Mar 12</td>
<td>6.3</td>
<td>4.9</td>
<td>3.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Average temperature, °C</td>
<td>Feb 23 to Mar 12</td>
<td>5.1</td>
<td>14.7</td>
<td>5.2</td>
<td>12.4</td>
</tr>
<tr>
<td>Average daily maximum temperature, °C</td>
<td>Feb 23 to Mar 12</td>
<td>12.1</td>
<td>19.7</td>
<td>10.5</td>
<td>18.4</td>
</tr>
<tr>
<td>Average daily minimum temperature, °C</td>
<td>Feb 23 to Mar 12</td>
<td>-0.7</td>
<td>9.7</td>
<td>-1.3</td>
<td>5.9</td>
</tr>
</tbody>
</table>

### Table 5. Average forage intake and pasture carrying capacity measures of cows with low and high residual feed intake (RFI) during Exp. 1 and average forage utilization and intake of cows with low and high RFI and their calves during Exp. 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low RFI1</th>
<th>High RFI1</th>
<th>SEM2</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMI, kg/(cow-d)</td>
<td>12.4</td>
<td>15.6</td>
<td>0.9</td>
<td>0.23</td>
</tr>
<tr>
<td>Area grazed,3 ha</td>
<td>1.71</td>
<td>1.82</td>
<td>0.05</td>
<td>0.35</td>
</tr>
<tr>
<td>DM on offer,4 kg</td>
<td>4,215</td>
<td>4,376</td>
<td>11</td>
<td>0.06</td>
</tr>
<tr>
<td>Exp. 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utilization,5 %</td>
<td>75.5</td>
<td>76.3</td>
<td>2.5</td>
<td>0.84</td>
</tr>
<tr>
<td>DMI, kg/(cow-calf pair-d)</td>
<td>12.5</td>
<td>14.1</td>
<td>0.7</td>
<td>0.12</td>
</tr>
</tbody>
</table>

1RFI were determined for these animals as heifers, while fed a hay diet.

2For $n = 2$ in Exp. 1 (2 replicate paddocks of 7 cows for each RFI group) and $n = 3$ in Exp. 2 (3 replicate paddocks of 4 cow-calf pairs for each RFI group).

3Average area of paddock (2 paddocks/RFI group) over 84-d trial.

4Average DM on offer per paddock (2 paddocks/RFI group) over 84-d trial, determined using paddock size per week and yield calculated by regression equation derived from rising plate meter readings and harvested yield data.

5Utilization calculated as the percentage of forage consumed using the pre- and post-sampling forage yield data and estimated growth for each period.
In a review of mechanisms for variation in RFI, Herd et al. (2004) attributed 14% of the variation observed to differences in digestion. Whether these differences are affected by type of diet is yet to be determined, however. It has been suggested that steer progeny from high RFI lines have decreased starch digestion (Channon et al., 2004), although it is unknown whether this is an effect of intake alone. Despite differences observed in starch digestion, no differences in forage DM digestibility were observed for cows (Herd et al., 1998) or stocker steers grazing pasture (Herd et al., 2002). Because heifers in the current study were consuming forage alone during RFI determination, efficiency differences observed should have been specific to forage-based diets.

The lack of intake differences from the pasture studies cited (Herd et al., 1998; Herd et al., 2002) may be due, at least in part, to the methods used to measure intake. This research group suggested in more recent reviews that although alkanes are accurate in the determination of intake in many pasture studies, this method may not be accurate enough to determine differences in grazed forage intake due to genetic improvement, including their previous experiments cited here (Arthur et al., 2004; Arthur and Herd, 2005).

Although there were no differences in intake between low and high RFI cows in the current study, this may be due to a lack of biological differences or to constraints of the experimental design limiting our ability to measure differences. First, animals were low in numbers and variation existed in age, physiological state, and sire and dam lines represented. Also, calves used in Exp. 2 were sired by bulls of unknown RFI classification, as few bulls in the United States currently have these data and no bulls have been produced from this breeding program yet. Because of this, the RFI of calves may have differed from dam RFI groups, and thus their intake may have negated some of the potential difference in DMI in Exp. 2.

Finally, forage intake is difficult to measure on pasture, especially with intact animals. Because of the problems associated with alkanes and other fecal markers, more indirect means of intake measurement were employed for these experiments. Although these methods provide reasonable estimates of DMI at each sampling point (Casler et al., 1998; Curtis et al., 2008), additional sampling periods improve the accuracy of DMI estimates. To maintain a practical labor load, fewer sampling dates and experimental units (paddocks) were used than ideal. Weather can also have a large impact upon forage sampling and results and cannot be controlled. Larger numbers need to be used to further investigate the intake difference of beef cows due to RFI classification or selected divergence.

In conclusion, low and high RFI cows had similar grazed forage intakes during gestation (Exp. 1) and late lactation (Exp. 2) while maintaining similar BW and condition in addition to weaning calves of similar BW. The magnitude of spread observed between low and high RFI cows in both experiments of this study warrants further research to explore any potentially biologically relevant differences that were not detected in this study. Difficulties exist with current methods and small animal numbers used to determine grazed forage intake, and further research in this area would be aided by the development of improved methodology.

LITERATURE CITED


Feed efficiency and cow grazed forage intake


