

Are low-residual feed intake cows adapted to rangelands?

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INTRODUCTION

Recently, renewed interest has been expressed in finding efficient beef cattle to fit a rangeland environment. As a rancher said at the 2015 Range Beef Cow Symposium (Olsen, 2015; <https://beef.unl.edu/2015-range-beef-cow-symposium>), “The area of production efficiency, and specifically feed efficiency, has plenty of room for improvement in the nation’s cow herd.”

Increased market value has been attached to bulls with favorable rankings for residual feed intake (RFI), which is expressed as the difference between expected feed intake (based upon body weight [BW] and growth) and actual feed intake. Although the cattle industry is on a trajectory of producing efficient (low-RFI) cattle, little is known about how this trait (measured in a feedlot setting) affects beef cattle efficiency on rangeland. Our objective was to determine if efficient heifers were also efficient as cows grazing rangeland and we hypothesized that foraging behavior (accessing difficult terrain, daily grazing, resting, and walking time) would differ among lactating 2-yr-old cattle divergently ranked for RFI. We also desired to determine if cattle BW, body condition score (BCS), and calf weaning weights were comparable among these RFI groups and we hypothesized there

would be no differences for these production characteristics among these divergent groups.

MATERIALS AND METHODS

Range Sites

This trial was conducted over spring and summer grazing periods in 2016 and 2017 at the Rinker Rock Creek Ranch located about 18 km southwest of Hailey, Idaho (114°23.509'W, 43°23.426'N). The ranch is described more fully at <https://www.uidaho.edu/cnr/rangeland-center/rock-creek> but consists of 4,209 ha private land and 4,452 ha of public land, the majority of the public land being administered by the Bureau of Land Management. Upland sagebrush-steppe pastures were grazed from June 14 to July 4 in 2016 in a 909-ha pasture (1,463 to 1,646 m elevation; slopes up to 68% but predominantly 0% to 15%) and from August 2 to 25 in a 1,345-ha pasture (1,510 to 1,726 m elevation; slopes up to 45% but predominantly 5% to 25%). Cattle grazed upland sagebrush-steppe pastures in 2017 in a 736-ha pasture from May 23 to June 12 (1,609 to 1,723 m elevation; slopes up to 60% but predominantly 5% to 15%) and from August 5 to 28 in the same late-season pasture used in 2016 with an added 64-ha pasture (1,510 to 1,726 m elevation; slopes up to 40% but predominantly 0% to 15%).

The mean annual precipitation (1981 to 2010) near the research sites at the Freidman

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Memorial Airport in Hailey, Idaho (114°18.171'W, 43°30.448'N, elevation 1,617 m) is 341 mm with 48% falling during April through September. Pastures are dominated by mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* [Rydb.] Beetle) with subdominant shrub species including antelope bitterbrush (*Purshia tridentata* [Pursh] DC.), and rabbitbrush (*Chrysothamnus* Nutt.). Prominent half-shrubs include sulphur-flower buckwheat (*Eriogonum umbellatum* Torr.). Dominant perennial grasses include Great Basin wildrye (*Leymus cinereus* [Scribn. & Merr.] A. Löve), Columbia needlegrass (*Achnatherum nelsonii* [Scribn.] Barkworth ssp. *Nelsonii*), Idaho fescue (*Festuca idahoensis* Elmer), sandberg bluegrass (*Poa secunda* Presl), prairie junegrass (*Koeleria macrantha* [Ledeb.] Schult.), bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve ssp. *spicata*), and bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey ssp. *Elymoides*). The dominant annual grass is cheatgrass (*Bromus tectorum*). Dominant forbs are arrowleaf balsamroot (*Balsamorhiza sagittata* [Pursh] Nutt.) and lupine (*Lupinus* L. spp.).

Animals and Grazing Behavior

All procedures were approved by the University of Idaho Animal Care and Use Committee (IACUC # 2015-44). Previously, all 2-yr-old cows used for grazing behavior were classified for RFI as being either efficient (EFF) or inefficient (INE) as yearling heifers (Hall et al., 2015).

Approximately mid-May of both 2016 and 2017, 160 Hereford × Angus mixed-age cattle were transported 372 km from the University of Idaho Nancy M. Cummings Research, Extension and Education Center at Carmen, Idaho (113°52.697'W, 45°17.322'N) to the Rinker Rock Creek Ranch. From within the main cowherd, a subset of divergently ranked (12 EFF; 12 INE), lactating 2-yr-old cows were fitted with home-made halters containing both a 3-axis accelerometer (USB Logger Model XB, Gulf Coast Data Concepts, LLC, Waveland, MS) and a global positioning system (GPS) logger (i-gotU GT-120; Mobile Action Technology, New Taipei City, Taiwan). Both the accelerometer and the GPS logger had a rechargeable Li-ion 3.7-V, 5,200-mAh battery (Tenenergy Li-ion 18650, Fremont, CA) soldered to the equipment to extend data logging. The two sample periods within each year were timed to gather grazing behavior data during mid- and late-lactation.

Daily grazing time (GT), resting time (RT), and walking time (WLK) were estimated every 5 s using the 3-axis accelerometer. Data were compiled using Python coding (<https://www.python.org/>). Observed daily activity for each cow was obtained by one to three observers over multiple time periods over 3 d at the beginning of each sampling period. This was necessary to obtain a “data signature” to match raw accelerometer output to daily grazing activity. Observational sampling occurred during peak grazing periods in early morning and late afternoon and during mid-day when cows rest. Reliable walking data were collected as cows were trailed to and from corrals.

Equations used to evaluate accelerometer *g* values included the x, y, and z axes and the equations $x + y + z$, $x \times z$, $x \times y + z$, average and maximum for movement intensity {SQRT of $(x^2 + y^2 + z^2)$ }, and the average and maximum for signal amplitude {ABS(x) + ABS(y) + ABS(z)}. These equations were evaluated for each cow using both error scores and plotted probability plots obtained from quadratic discriminant analysis (SAS, v. 9.4; SAS Institute, Inc., Cary, NC). The equations chosen to separate daily activity were summarized by d for each 2-h time period beginning at midnight.

The GPS loggers recorded locations at 7-min intervals in 2016 and at 4-min intervals in 2017 and daily travel distance (DTD) along the travel path was calculated. In addition, the daily averages for elevation (EL) and the amount of time spent on slopes greater than 15% were (SLP) calculated. All waypoints exceeding 84 m/min travel time and all waypoints exceeding 300 m estimated horizontal positional error were eliminated. Also, points with altitudes <1,300 or >2,000 m from the data loggers were eliminated. In ArcMap (v. 10.2.2; Esri, Inc., Redlands, CA), GPS positions appearing outside of the mapped fenceline were deleted. Data were then compared from day to day, and those points sharply diverging from the general path were deleted.

Statistical Analyses

Daily GT, RT, WLK, DTD, EL, and SLP were analyzed with a mixed effects model for repeated measures (v. 9.4, SAS Institute, Inc.) by sample period with the fixed effects of RFI group, date, and the interaction between RFI group × date. Cow within RFI group was included as a random repeated subject. The GPS data from May 2017 only contained the fixed effects of RFI group and RFI group × date due to several missing daily values for cows that were eliminated because they were

in the wrong pasture. The denominator degrees of freedom for all grazing behavior F-statistics were approximated using the Kenward–Roger's method. For all models, a simplified compound symmetry covariance structure was used to model the relationships between repeated observations. Cow BW, BCS, and adjusted calf weaning weight were analyzed by a general linear least squares model with RFI group as a fixed main effect. Least squares treatment means for all statistical models were separated using the pairwise contrasts (PDIFF, v. 9.4, SAS Institute, Inc.).

RESULTS AND DISCUSSION

Climatic Data

The average maximum and minimum daily temperatures at the Freidman Memorial Airport weather station for each sample period were as follows: June 14 to July 4, 2016 (25.9 and 9.4 °C),

August 2 to 25, 2016 (27.8 and 10.6 °C), May 23 to June 12, 2017 (21.3 and 6.8 °C), and August 5 to 28, 2017 (27.5 and 11.4 °C). Precipitation received at the Bellevue, Idaho weather station (114.26 °W, 43.46 °N, elevation 1,584 m, 13.5 km NE of study sites) from April through September was 133 mm in 2016 and 118 mm in 2017.

Grazing Behavior

When GT, RT, and WT means were compared for all grazing periods (Table 1), there were no differences ($P > 0.10$) observed. Similarly, there were no differences in DTD or in the elevational gradient cows accessed ($P > 0.10$). However, the interaction of day with RFI group was important ($P < 0.05$) or tended ($P > 0.10$) to be important for 50% of the sample periods for EL and GT and 25% of the sample periods for RT. These significant interactions were most prominent when temperatures were hotter or cooler for several days in succession. For example,

Table 1. Grazing behavior for lactating 2-yr-old cows on Idaho rangeland

| Item | Efficient cows ¹ | <i>n</i> | Inefficient cows ¹ | <i>n</i> | <i>P</i> -value |
|--|-----------------------------|----------|-------------------------------|----------|-----------------|
| June 14 to July 4, 2016 | | | | | |
| DTD, km/d ² | 6.4 ± 0.19 | 11 | 6.3 ± 0.21 | 10 | 0.5156 |
| Percentage of time on slopes >15% | 16.5 ± 1.51 | 11 | 15.3 ± 1.59 | 10 | 0.5912 |
| Average elevation for day, m | 1,521 ± 2.8 | 11 | 1,518 ± 3.0 | 10 | 0.6590 |
| Grazing, h/d | 10.7 ± 0.49 | 11 | 10.3 ± 0.57 | 11 | 0.6993 |
| Resting, h/d | 10.3 ± 0.46 | 11 | 10.3 ± 0.51 | 11 | 0.9902 |
| Walking, h/d | 2.7 ± 0.41 | 11 | 3.3 ± 0.46 | 11 | 0.3317 |
| August 2 to 25, 2016 | | | | | |
| DTD, km/d | 7.4 ± 0.23 | 12 | 7.6 ± 0.23 | 12 | 0.8059 |
| Percentage of time on slopes >15% | 16.9 ± 2.7 | 12 | 17.2 ± 2.7 | 12 | 0.8059 |
| Average elevation for day, m ² | 1,549 ± 2.9 | 12 | 1,542 ± 2.9 | 12 | 0.1282 |
| Grazing, h/d ³ | 10.2 ± 0.22 | 12 | 10.2 ± 0.22 | 12 | 0.9690 |
| Resting, h/d | 11.3 ± 0.17 | 12 | 11.0 ± 0.17 | 12 | 0.2728 |
| Walking, h/d | 2.5 ± 0.19 | 12 | 2.7 ± 0.19 | 12 | 0.3883 |
| May 23 to June 12, 2017 | | | | | |
| DTD, km/d ² | 6.0 ± 0.83 | 12 | 6.4 ± 0.64 | 11 | 0.7397 |
| Percentage of time on slopes >15% ² | 7.0 ± 0.95 | 12 | 6.0 ± 1.03 | 11 | 0.4835 |
| Average elevation for day, m ² | 1,655 ± 3.8 | 12 | 1,658 ± 3.3 | 11 | 0.6404 |
| Grazing, h/d ³ | 10.3 ± 0.25 | 11 | 10.8 ± 0.26 | 10 | 0.1734 |
| Resting, h/d | 10.9 ± 0.30 | 11 | 10.7 ± 0.32 | 10 | 0.7277 |
| Walking, h/d | 2.9 ± 0.20 | 11 | 2.5 ± 0.21 | 10 | 0.1949 |
| August 5 to 28, 2017 | | | | | |
| DTD, km/d | 6.9 ± 0.41 | 11 | 6.7 ± 0.20 | 10 | 0.5619 |
| Percentage of time on slopes >15% | 4.3 ± 1.97 | 11 | 3.2 ± 0.98 | 10 | 0.6395 |
| Average elevation for day, m | 1,590 ± 2.1 | 11 | 1,586 ± 2.2 | 10 | 0.1247 |
| Grazing, h/d | 11.6 ± 0.54 | 10 | 10.7 ± 0.55 | 11 | 0.2702 |
| Resting, h/d ³ | 10.5 ± 0.76 | 10 | 10.7 ± 0.60 | 11 | 0.8516 |
| Walking, h/d | 2.2 ± 0.34 | 10 | 2.8 ± 0.32 | 11 | 0.2875 |

¹Efficient cows were ranked as low-residual feed intake and Inefficient cows were ranked as high-residual feed intake as yearling heifers.

²Day × treatment interaction present, $P < 0.05$.

³Tendency for day × treatment interaction, $P < 0.10$.

August 2016 had 7 of 9 d in succession when maximum daily temperatures were $\geq 29.4^\circ\text{C}$ and the temperature humidity index (THI) exceeded 72. When the THI is ≥ 72 and < 79 a beef cow is considered to be in mild heat load and when THI is ≥ 79 , cows are considered to be in severe heat load. On 57% of those days in August described earlier, EFF cows exhibited a behavioral response superior to INE cows by either climbing higher or grazing longer or both ($P < 0.10$). Conversely, the May 24 to June 12 grazing period was characterized by only 1 d being above 29.4°C and INE cattle grazed 1.7 h more each day than EFF cows ($P < 0.05$) for the 5-d period from May 31 to June 4 (25% of the total grazing days).

Figure 1 presents a striking comparison for cattle grazing locations during August 2016 and Figure 2 presents an example of a day \times RFI group

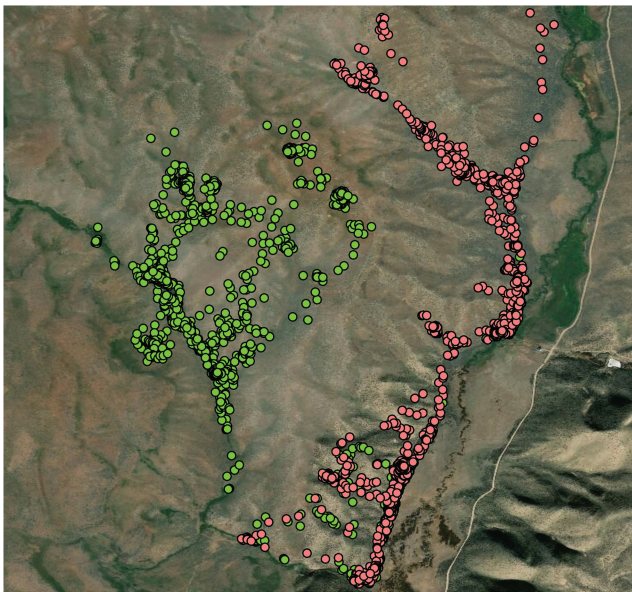


Figure 1. Efficient vs. inefficient cow grazing locations during hot days in August 2016. Efficient cow is shown in green and inefficient cow is shown in pink. Pink dots are at lower elevations with more shade. These two cows are representative of their groups.

interaction on two contrasting days in August of 2016. The INE cattle spent more time at lower elevations ($P < 0.05$) and presumably more time in the shade during the extended time period in August of 2016 with elevated temperatures. The INE cows grazed 1.5 h more than EFF cows ($P < 0.05$) on a cooler day (23.3°C) and 2.0 h less than EFF cows ($P < 0.05$) on a hotter day (30.6°C) in August of 2016 (Figure 2).

The cows in this study also exhibited differences in behavior when experiencing mild heat loads during a 7-d successive period in June 2016. During this period, maximum daily temperatures exceeded 29.4°C and EFF cattle demonstrated superior behavior for this rugged rangeland pasture 29% of the time for the 7-d period. On July 1, EFF cows walked 2.7 km further ($P < 0.0001$) than INE cows and on July 3, they walked 2.3 km further ($P = 0.0008$). It should be mentioned that INE cows did have 1 d during this time period (June 28) when they traveled 1.6 km further ($P = 0.0428$) than EFF cows. On that day, afternoon wind gusts prevailed for approximately 4 h, starting at 1500 hours. On July 1 and 3, EFF cows tended ($P < 0.10$) to climb higher than INE cows.

During August 2017, the temperatures were milder with temperatures exceeding 29.4°C on 12, 22, and 25 to 28 August. During the 4-d period at the end of the trial, EFF cows tended ($P = 0.0658$) to climb higher up on the slopes than did INE cattle on August 27. During August 2017, EFF cows grazed 1.9 h more than INE cows ($P < 0.10$) on three cooler days when temperatures were 26.1, 24.4, and 21.1°C .

Presumably, INE cows would be expected to have greater appetite than EFF cows and should increase daily GT when conditions are favorable. Yet, greater appetites are accompanied by larger gastrointestinal tracts (Sprinkle et al., 2000), increasing metabolic heat load and reducing heat tolerance.

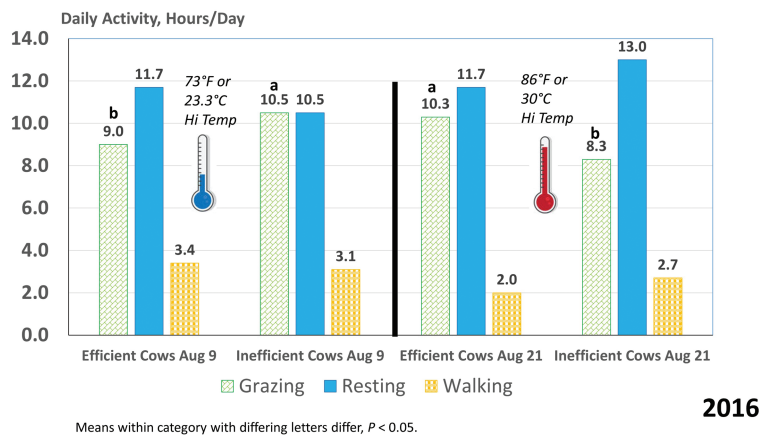


Figure 2. On a cool day, inefficient cows grazed 1.5 h longer than efficient cows but on a hot day they grazed 2 h less than efficient cows.

Table 2. Cow and calf production data for lactating 2-yr-old cows on rangeland

| Item | Efficient cows ¹ | <i>n</i> | Inefficient cows ¹ | <i>n</i> | <i>P</i> -value |
|---|-----------------------------|----------|-------------------------------|----------|-----------------|
| 2016 | | | | | |
| August 1 cow BW, kg | 458 ± 9.8 | 12 | 462 ± 9.8 | 12 | 0.7697 |
| August 1 cow BCS | 5.4 ± 0.19 | 12 | 5.5 ± 0.19 | 12 | 0.7640 |
| September 12 adjusted weaning wt, kg ² | 259 ± 6.2 | 12 | 257 ± 6.2 | 12 | 0.7778 |
| 2017 | | | | | |
| July 28 cow BW, kg | 448 ± 10.1 | 12 | 448 ± 10.1 | 12 | 0.9730 |
| July 28 1 BCS | 4.4 ± 0.21 | 12 | 4.3 ± 0.21 | 12 | 0.7811 |
| September 13 cow BW, kg | 458 ± 10.3 | 11 | 464 ± 10.8 | 10 | 0.7088 |
| September 13 cow BCS | 4.6 ± 0.17 | 11 | 4.8 ± 0.18 | 10 | 0.5181 |
| September 13 adjusted weaning wt, kg ² | 264 ± 5.8 | 12 | 258 ± 5.8 | 12 | 0.4284 |

¹Efficient cows were ranked as low-residual feed intake and Inefficient cows were ranked as high-residual feed intake as yearling heifers.

²Calf weights adjusted to 205 d.

This could limit the ability of INE cattle to graze to appetite when experiencing an extended time period with elevated temperatures.

The results presented here from both GPS and accelerometer data indicate that cattle ranked as EFF via RFI also function competitively in rangeland environments. Cows that have the genetics for improved feed efficiency exhibited compensatory behavior when compared to their inefficient herdmates following extended periods with elevated summer temperatures. This compensatory behavior enabled these cattle to access more difficult terrain and distribute more evenly on rangeland during extended time periods with elevated summertime temperatures. On public land ranches with endangered fish or riparian area concerns, this may add further value to these efficiently ranked cows. Recent research (Pierce, 2019) suggests that genetic markers may exist to classify cows that better fit rugged rangeland environments and that there may be a relationship between RFI classification and terrain use by beef cattle.

A matter of concern is whether EFF cows are able to maintain similar BW and BCS and calf weaning weights when grazing rangeland. Table 2 illustrates the results obtained for this small dataset of 2-yr-old cows on Idaho rangeland in 2016 and 2017. EFF cattle performed similarly ($P > 0.10$) to INE cattle in this rangeland setting. We will continue to gather production data over a period of years and will be evaluating fertility, longevity, and profitability of divergently ranked cattle for feed efficiency in both an irrigated and rangeland environment.

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Conflict of interest statement. None declared.

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