Relationships of feeding behaviors with average daily gain, dry matter intake, and residual feed intake in Red Angus–sired cattle[1]

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ABSTRACT: Feeding behavior has the potential to enhance prediction of feed intake and to improve understanding of the relationships between behavior, DMI, ADG, and residual feed intake (RFI) in beef cattle. Two cohorts, born in 2009 and 2010, the progeny of Red Angus bulls ($n = 58$ heifers and $n = 53$ steers), were evaluated during the growing phase, and the latter group of steers was also evaluated during the finishing phase. All behavior analyses were based on 7 feeding behavior traits (bunk visit frequency, bunk visit duration [BVDUR], feed bout frequency, feed bout duration, meal frequency, meal duration, and average meal intake) and their relationships with ADG, DMI, and RFI. During the growing phase, feeding duration traits were most indicative of DMI with positive correlations between BVDUR and DMI for cohort 1 steers, growing phase ($n = 28$, $r = 0.52$, $P = 0.00$); cohort 2 steers, growing phase ($n = 25$, $r = 0.44$, $P = 0.01$); and cohort 2 heifers, growing phase ($n = 29$, $r = 0.28$ $P = 0.05$). There were similar trends toward correlation of BVDUR and RFI for both steer groups and cohort 1 heifers, growing phase (C1HG; $n = 29$; $r = 0.27$, $P = 0.06$; $r = 0.30$, $P = 0.07$; and $r = 0.26$, $P = 0.08$, respectively). Feed bout frequency was correlated with ADG in C1HG and in cohort 2 steers, finishing phase ($r = –0.31$, $P = 0.04$, and $r = 0.43$, $P = 0.01$, respectively). Feed bout duration was correlated with ADG in heifer groups ($r = 0.29$ and $r = 0.28$, $P = 0.05$ for both groups) and DMI for all growing phase animals ($r = 0.29$ to 0.55, $P \leq 0.05$ for all groups). Evaluation of growing vs. finishing phase steer groups suggests that all behaviors, RFI, and DMI, but not ADG, are correlated through the growing and finishing phases ($P \leq 0.01$ for all variables excluding ADG), implying that feeding behaviors determined during the growing phase are strong predictors of DMI in either life stage. Sire maintenance energy EPD effects (measured as high or low groups) on progeny feeding behaviors revealed a difference in meal duration with a tendency to differ in average meal intake ($P = 0.01$ and $P = 0.07$, respectively). Feeding behavior duration traits may be useful predictors of DMI in Red Angus cattle.

Key words: efficiency, feeding behavior, Red Angus, residual feed intake

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INTRODUCTION

With the recent increase in feed costs (since 2006), there has been a greater need to identify methods to reduce input costs in the beef industry. An improvement in feed efficiency can reduce input costs as well as maximize profits (Archer et al., 1999; Miller et al., 2001; Basarab et al., 2007). Previous research denotes individual animal variation of feed intake above and below that anticipated using size and growth rate indicators (Herd et al., 2003a,b). Residual feed intake (**RFI**) provides a tool that takes advantage of natural variability in feed efficiency that is independent of traits that are important in the breeding herd (Tedeschi et al., 2006). Residual feed intake identifies efficient animals (Koch et al., 1963) by measuring the difference between expected and actual animal feed intake through regression of growth over a specified time period. This methodology has been proven successful; however, underlying biological mechanisms

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surrounding these variations are still unclear. Herd et al. (2004) found that feeding behavior contributed to 2% of the variation in RFI. Other research, however, has suggested that an animal's feeding behavior can account for a higher percentage (35%) of this deviation (Lancaster et al., 2009). Radio frequency identification–equipped animal feed intake systems allow researchers to examine large populations of animals with individual parameters, including patterns of feed intake and associated behaviors. The current study aims to provide insights into the prediction of DMI and variations of efficiency status using feeding behavior parameters.

MATERIALS AND METHODS

Procedures involving the use of animals in this study were approved by the University of Idaho Animal Care and Use Committee (2011-3).

Animals and Adaptation for Residual Feed Intake Calculation

The current study is associated with a larger evaluation of the progeny of Red Angus sires. For a more detailed description of sires and progeny postweaning RFI evaluation and finishing phase feed efficiency evaluation, please refer to Welch et al. (2012). In brief, a total of 12 Red Angus sires divergent for maintenance energy (**ME_M**) EPD were chosen based on the Red Angus Association of America–generated ME_M EPD (RAAA, 2011). Crossbred cows were estrus synchronized and bred by AI over 3 yr, with each sire being represented across 2 to 3 cohorts and 11 out of 12 sires producing 15 or more progeny. The current study evaluates progeny from the latter 2 yr of this study, henceforth designated by sex, cohort, and either growing or finishing phase evaluation as follows: cohort 1 heifers, growing phase (**C1HG**; *n* = 29); cohort 1 steers, growing phase (**C1SG**; *n* = 28); cohort 2 heifers, growing phase (**C2HG**; *n* = 29); cohort 2 steers, growing phase (**C2SG**; *n* = 25); and cohort 2 steers, finishing phase (**C2SF**; *n* = 25).

Red Angus steers (*n* = 53) and heifers (*n* = 58) were evaluated using electronic individual feed intake recording equipment (GrowSafe Systems Ltd, Airdrie, AB, Canada) at the University of Idaho Nancy M. Cummings Research, Education, and Extension Center (**NMCREEC**; Carmen, ID). Animals were adapted to the GrowSafe system using stability of intake as the primary indicator of test initiation. Acclimation was generally for 2 wk before the test periods. Animals were weighed in mornings (before feeding) for 2 consecutive days at trail initiation and termination and also weighed every 2 wk (before feeding) for ADG and RFI determinations. The GrowSafe system at NMCREEC is composed of 4 (21.34 by 54.86 m) pens each containing 5 feeding nodes. The pens are located outside without cover. Animals were randomly allocated (within sex) to 1 of 4 pens of the GrowSafe feed intake monitoring system. Ultrasound procedures were performed for live animal carcass characteristics by an independent technician. Ultrasound measurements included rib fat (**RF**) thickness, intramuscular fat (**IMF**), and LM area. Measurements were performed on d 0 and 70 between the 12th and 13th ribs. All images were captured by an Aloka 500ssd Scanner (Hitachi Aloka Medical, Ltd., Wallingford, CT).

The C2SG group growing diet was modified (Table 1) to a finishing phase diet through 4 steps after a postweaning (growing phase) RFI evaluation. During this final finishing period, this group of steers, designated C2SF, was evaluated for individual DMI, ADG, finishing phase feed efficiency, and feeding behaviors. Test protocols used for postweaning RFI evaluations were also implemented for finishing phase feed efficiency evaluation. Steers were finished to a target BW of 591 kg (group average) before harvest, resulting in a recorded intake period of approximately 110 d (including all modifications of the finishing rations).

After RFI evaluation, RFI-divergent groups (defined as efficient: RFI > 0.5 SD below the mean, and inefficient: RFI > 0.5 SD above the mean) were examined for feeding behaviors based on data collected from the GrowSafe output. Behaviors analyzed were classified as bunk visit data, feed bout data, and meal data. Bunk visit

Table 1. Ingredient (% DM basis), chemical composition, and energy values of diets fed to Red Angus cohorts

Item[1]	Grower diet[2]	Finishing diet[3]
Alfalfa hay midbloom	60.0	31.0
Corn grain cracked	30.0	46.0
Molasses	10.0	13.0
Distillers grain soluble	–	10.0
Rumax FL10[4]	8.1	10.5
Dry matter, %	80.9	81.1
Crude protein, %	16.4	15.2
Fiber crude, %	20.7	12.3
Fat (EE), %	2.3	3.9
NEm,[5] Mcal/kg	1.6	1.9
NEg,[5] Mcal/kg	0.9	1.1
Ash, %	8.1	6.8

[1]EE = ether extracted.

[2]Cohort 1 steers, growing phase (*n* = 28); cohort 1 heifers, growing phase (*n* = 29); cohort 2 heifers, growing phase (*n* = 29); and cohort 2 steers, growing phase (*n* = 25).

[3]Cohort 2 steers finishing phase (*n* = 25).

[4]Vitamin premix ingredients: corn soy blend, cane molasses, corn steep, ammonium polyphosphate, salt, limestone, Attaflow, whey, water, fat, anhydrous ammonia, Deccox 6%, zinc sulfate, manganese sulfate, copper sulfate, vitamin E premix 60%, selenium 4%, vitamin A 1,000, cobalt sulfate ethylenediamine dihydriodide (organic iodized salt), and vitamin D_3 500.

[5]NEm and NEg are calculated values.

parameters were bunk visit frequency (**BVFREQ**; transponder readings for a single animal entering feed bunk) and bunk visit duration (**BVDUR**; time during transponder readings with animal at bunk, ending when there are no readings for >300 s). Feed bout behaviors are feed bout frequency (**FBFREQ**; transponder readings for single animal entering feed bunk and consuming feed) and feed bout duration (**FBDUR**; time during transponder reading with animal at bunk consuming feed, ending when the time between the last 2 readings was >300 s or when a new transponder was detected). Meal data has 3 behavior parameters: meal frequency (**MFREQ**; cluster of feed bouts in which the nonfeeding event was shorter than meal criterion), meal duration (**MDUR**; time during transponder readings with animal at bunk consuming feed per meal), and average meal intake (**AMINT**; sum of feed event intakes during a meal). The meal criterion used in the present study was 300 s as described by Schwartzkopf-Genswein et al. (2002). Groups of animals (C1SG, C1HG, C2HG, C2SG, and C2SF) were examined by efficiency classification (efficient: C1SG, $n = 14$; C1HG, $n = 14$; C2HG, $n = 15$; C2SG, $n = 12$; and C2SF, $n = 13$; inefficient: C1SG, $n = 14$; C1HG, $n = 15$; C2HG, $n = 14$; C2SG, $n = 12$; and C2SF, $n = 13$.

Statistical Analysis

Residual feed intake analyses were conducted using SAS (version 9.2; SAS Inst. Inc., Cary, NC). Residual feed intake was calculated as the difference between actual and predicted feed intake by regressing DMI on midtest $BW^{0.75}$ and ADG (Koch et al., 1963) with the addition of RF thickness (Basarab et al., 2003) to the model. Coefficients of determination for RFI prediction for each group were as follows: C1HG, 0.76; C1SG, 0.89; C2HG, 0.68; C2SG, 0.39; and C2SF, 0.42.

After RFI tests, animals were classified into the following groups: efficient (RFI > 0.5 SD below the mean), marginal (RFI ± 0.5 SD of the mean), and inefficient (RFI > 0.5 SD above the mean).

Feeding behavior parameters were examined for each RFI test phase by Spearman's rank correlation with ADG, DMI, and RFI values. Each behavior was averaged over days within each of the 4 test periods. With these averages, a mixed model repeated measures completely random design was used to assess feeding behaviors considering RFI group as a fixed effect and the 4 test periods as a repeated measure, with animals considered as random effects. An autoregressive lag 1 correlation structure was assumed for the repeated effect of test period. The PROC MIXED procedures of SAS were used to examine these effects. The effect of sire ME_M EPD on progeny feeding behaviors was measured by defining high or low sire ME_M EPD. For further details of sire classification, please see Welch et al. (2012). Pairwise comparisons of least squares group means was performed for all responses. An α of 0.05 was set to designate statistically significant differences.

RESULTS

Performance and Behavior of Divergent Residual Feed Intake Cohort Groups

Mean BW (initial and final), ADG, and RF thickness were similar among efficiency groups within Red Angus cohorts (Table 2; $P > 0.10$ for all traits). As expected, DMI and RFI differed between efficiency classifications within cohorts ($P < 0.01$ for all cohorts). Behavior traits BVFREQ, BVDUR, FBFREQ, FBDUR, MFREQ, MDUR, and AMINT were similar among efficiency classifications within Red Angus cohorts ($P > 0.10$ for all).

Associations of Feeding Behaviors with ADG, DMI, and Residual Feed Intake

Spearman rank correlations between behaviors and ADG, DMI and RFI are presented in Table 3. Behavior BVFREQ was significantly correlated with ADG only in C2SF ($r = 0.43$, $P = 0.01$). Conversely, there was a tendency towards negative correlation between BVFREQ and ADG in C1HG ($r = –0.29$, $P = 0.06$). There were no significant correlations between BVFREQ and DMI or RFI across any cohorts of Red Angus cattle.

Bunk visit duration indicated some associations with ADG in growing Red Angus heifers (C1HG and C2HG; $r = –0.29$, $P = 0.06$, and $r = –0.13$, $P = 0.07$, respectively). Bunk visit duration was significantly correlated with DMI in C1SG, C2HG, and C2SG ($r = 0.52$, $P < 0.0001$; $r = 0.28$, $P = 0.05$; and $r = 0.44$, $P = 0.01$, respectively), with a similar trend in C1HG ($r = 0.28$, $P = 0.06$), with no relationship between BVDUR and DMI in C2SF. Moderate correlation of BVDUR with RFI was detected in C1HG, C1SG, and C2SG ($r = 0.26$, $P = 0.08$; $r = 0.27$, $P = 0.06$; and $r = 0.30$, $P = 0.07$, respectively). No significant correlations were found between BVDUR and RFI in C2HG or C2SF.

Feed bout frequency and ADG were negatively correlated in C1HG yet positively correlated in C2SF ($r = –0.31$, $P = 0.04$, and $r = 0.43$, $P = 0.01$). Behavior FBFREQ and DMI were not correlated for any cohort ($P > 0.10$ for all). Similarly, FBFREQ and RFI were unrelated for all cohorts.

Feed bout duration and ADG were positively correlated in C1HG and C2HG, with a similar trend in C1SG ($r = 0.29$, $P = 0.05$; $r = 0.28$, $P = 0.28$; and $r = 0.26$, $P = 0.08$, respectively). Feed bout duration was significantly correlated with DMI for all growing phase groups (C1HG, C1SG, C2HG, and C2SG; $P \leq 0.05$ for all) but

Table 2. Comparison of means ± SE between residual feed intake (RFI)–efficient and RFI-inefficient Red Angus steers and heifers for performance measures and feeding behaviors

Measurement	Cohort[1]	Efficient	Inefficient	*P*
Initial BW, kg	C1HG	305 ± 10.3	306 ± 9.90	0.96
	C1SG	320 ± 10.4	322 ± 10.4	0.92
	C2HG	307 ± 8.23	307 ± 8.56	0.96
	C2SG	332 ± 8.08	323 ± 8.44	0.44
	C2SF	503 ± 10.3	513 ± 9.85	0.47
Final BW, kg	C1HG	427 ± 13.2	428 ± 12.7	0.97
	C1SG	448 ± 12.6	454 ± 12.6	0.75
	C2HG	411 ± 11.5	419 ± 11.9	0.67
	C2SG	450 ± 10.6	454 ± 11.1	0.83
	C2SF	593 ± 11.8	608 ± 11.3	0.37
ADG, kg/d	C1HG	1.47 ± 0.05	1.45 ± 0.05	0.78
	C1SG	1.62 ± 0.05	1.63 ± 0.05	0.92
	C2HG	1.27 ± 0.05	1.31 ± 0.50	0.67
	C2SG	1.48 ± 0.11	1.52 ± 0.12	0.80
	C2SF	1.28 ± 0.06	1.36 ± 0.50	0.35
DMI, kg/d	C1HG	10.7 ± 0.34	11.9 ± 0.33	<0.01
	C1SG	10.6 ± 0.29	12.2 ± 0.28	<0.01
	C2HG	10.1 ± 0.26	11.7 ± 0.27	<0.01
	C2SG	10.3 ± 0.24	12.3 ± 0.25	<0.01
	C2SF	12.6 ± 0.31	15.0 ± 0.30	<0.01
Rib fat thickness, cm	C1HG	1.22 ± 0.08	1.22 ± 0.07	0.99
	C1SG	1.14 ± 0.08	1.16 ± 0.08	0.81
	C2HG	1.02 ± 0.06	0.99 ± 0.06	0.68
	C2SG	1.05 ± 0.06	1.07 ± 0.07	0.82
	C2SF	1.41 ± 0.10	1.41 ± 0.09	0.99
RFI, kg/d	C1HG	–0.71 ± 0.10	0.68 ± 0.09	<0.01
	C1SG	–0.77 ± 0.10	0.70 ± 0.10	<0.01
	C2HG	–0.75 ± 0.09	0.76 ± 0.09	<0.01
	C2SG	–0.93 ± 0.11	1.03 ± 0.12	<0.01
	C2SF	–1.07 ± 0.13	0.96 ± 0.12	<0.01
Bunk visit frequency, events/d	C1HG	74.3 ± 4.96	83.3 ± 4.79	0.20
	C1SG	68.3 ± 3.47	74.3 ± 3.47	0.23
	C2HG	77.4 ± 3.76	79.9 ± 3.89	0.64
	C2SG	43.4 ± 2.93	50.6 ± 3.06	0.10
	C2SF	40.5 ± 1.78	42.5 ± 1.71	0.41
Bunk visit duration, min/d	C1HG	138 ± 5.07	148 ± 4.90	0.14
	C1SG	118 ± 4.69	129 ± 4.69	0.12
	C2HG	150 ± 4.74	156 ± 4.91	0.40
	C2SG	138 ± 5.80	153 ± 6.06	0.09
	C2SF	97.9 ± 3.52	104 ± 3.38	0.24
Feed bout frequency, events/d	C1HG	63.5 ± 4.06	68.9 ± 2.99	0.35
	C1SG	57.3 ± 2.99	61.8 ± 2.99	0.29
	C2HG	65.8 ± 3.47	66.3 ± 3.60	0.92
	C2SG	36.4 ± 2.54	42.3 ± 2.65	0.12
	C2SF	35.8 ± 1.62	38.4 ± 1.56	0.26
Feed bout duration, min/d	C1HG	134 ± 4.92	144 ± 4.75	0.14
	C1SG	115 ± 4.62	125 ± 4.62	0.13
	C2HG	145 ± 4.63	151 ± 4.80	0.42
	C2SG	135 ± 5.69	149 ± 5.95	0.12
	C2SF	96.0 ± 3.41	102 ± 3.28	0.20
Meal frequency, events/d	C1HG	11.6 ± 1.57	12.8 ± 1.51	0.20
	C1SG	10.1 ± 1.40	12.7 ± 1.40	0.20
	C2HG	12.8 ± 1.33	13.3 ± 1.37	0.79
	C2SG	9.31 ± 1.72	10.6 ± 1.79	0.60
	C2SF	8.60 ± 1.08	10.0 ± 1.04	0.38
Meal duration, min/d	C1HG	227 ± 12.7	222 ± 12.3	0.79
	C1SG	206 ± 14.0	209 ± 14.0	0.86
	C2HG	228 ± 11.3	236 ± 11.7	0.63
	C2SG	219 ± 22.3	235 ± 23.3	0.62
	C2SF	158 ± 14.8	148 ± 14.2	0.60
Average meal intake, kg/event	C1HG	1.40 ± 0.19	1.35 ± 0.19	0.85
	C1SG	1.54 ± 0.18	1.39 ± 0.18	0.54
	C2HG	1.24 ± 0.13	1.30 ± 0.13	0.75
	C2SG	1.77 ± 0.31	2.04 ± 0.32	0.55
	C2SF	2.32 ± 0.39	2.40 ± 0.37	0.89

[1]C1SG = cohort 1 steers, growing phase (n = 28); C1HG = cohort 1 heifers, growing phase (n = 29); C2HG = cohort 2 heifers, growing phase (n = 29); C2SG = cohort 2 steers, growing phase (n = 25); C2SF = cohort 2 steers, finishing phase (n = 25).

was not correlated in finishing phase steers. Behavior FBDUR and RFI trended towards a positive correlation in C1HG and C1SG (P = 0.08 and P = 0.09 for heifers and steers, respectively).

Meal frequency and ADG were unrelated across all cohorts (P > 0.10) as was MFREQ and DMI. There was a trend towards positive correlation between MFREQ and RFI (P = 0.09) in the C1SG group only. Meal duration was not correlated with ADG, DMI, or RFI for any cohort. Behavior AMINT trended towards positive correlations with both ADG and DMI in C1HG (both P = 0.06).

Relationships of Performance and Feeding Behaviors between Growing and Finishing Phase Red Angus Steers

In comparing growing and finishing phase Red Angus steer groups, ADG was not correlated (P = 0.56; Table 4) while DMI was strongly correlated (r = 0.56, P < 0.01). Similar to DMI, RFI was also strongly correlated between the growing and finishing phases (r = 0.50, P = 0.01). All 7 behaviors were also strongly correlated between growing and finishing phases (P < 0.01 for all behaviors).

Effects of Sire Maintenance Energy EPD on Performance and Feeding Behaviors of Red Angus Progeny

Table 5 shows the effects of sire ME_M EPD group (low ME_M EPD vs. high ME_M EPD) on progeny feeding behaviors. Meal duration of the high ME_M EPD sired group was greater than for their low ME_M EPD progeny counterparts (P = 0.01). There was a trend towards the

Table 3. Spearman's rank correlations of feeding behaviors with ADG, DMI, and residual feed intake (RFI) of Red Angus steers and heifers

Behavior	Cohort[1]	ADG r (P)	DMI r (P)	RFI r (P)
Bunk visit frequency, events/d	C1HG	–0.29 (0.06)	–0.15 (0.32)	0.15 (0.38)
	C1SG	–0.22 (0.14)	–0.17 (0.27)	0.14 (0.34)
	C2HG	–0.13 (0.35)	–0.22 (0.13)	0.01 (0.92)
	C2SG	0.19 (0.27)	0.17 (0.30)	0.20 (0.24)
	C2SF	0.43 (0.01)	0.22 (0.19)	0.16 (0.34)
Bunk visit duration, min/d	C1HG	0.29 (0.06)	0.28 (0.06)	0.26 (0.08)
	C1SG	0.22 (0.14)	0.52 (0.00)	0.27 (0.06)
	C2HG	0.26 (0.07)	0.28 (0.05)	0.13 (0.37)
	C2SG	0.19 (0.25)	0.44 (0.01)	0.30 (0.07)
	C2SF	0.06 (0.74)	0.16 (0.35)	0.21 (0.21)
Feed bout frequency, events/d	C1HG	–0.31 (0.04)	–0.19 (0.21)	0.09 (0.57)
	C1SG	–0.18 (0.23)	–0.15 (0.30)	0.15 (0.32)
	C2HG	–0.12 (0.40)	–0.19 (0.18)	–0.01 (0.95)
	C2SG	0.18 (0.30)	0.15 (0.38)	0.20 (0.23)
	C2SF	0.43 (0.01)	0.27 (0.11)	0.22 (0.19)
Feed bout duration, min/d	C1HG	0.29 (0.05)	0.29 (0.05)	0.26 (0.08)
	C1SG	0.26 (0.08)	0.55 (<0.01)	0.25 (0.09)
	C2HG	0.28 (0.05)	0.31 (0.03)	0.11 (0.45)
	C2SG	0.21 (0.21)	0.44 (0.01)	0.10 (0.54)
	C2SF	0.06 (0.74)	0.16 (0.33)	0.22 (0.19)
Meal frequency, events/d	C1HG	–0.10 (0.52)	–0.18 (0.25)	0.10 (0.51)
	C1SG	0.03 (0.85)	0.15 (0.32)	0.25 (0.09)
	C2HG	0.07 (0.64)	0.06 (0.66)	0.02 (0.89)
	C2SG	0.05 (0.76)	–0.03 (0.87)	0.03 (0.87)
	C2SF	0.00 (1.00)	0.23 (0.16)	0.08 (0.64)
Meal duration, min/d	C1HG	–0.06 (0.69)	–0.06 (0.69)	0.02 (0.88)
	C1SG	–0.11 (0.45)	0.01 (0.96)	0.08 (0.61)
	C2HG	0.06 (0.69)	0.00 (0.97)	–0.03 (0.85)
	C2SG	–0.01 (0.95)	0.15 (0.37)	0.10 (0.54)
	C2SF	0.12 (0.50)	–0.16 (0.34)	–0.04 (0.82)
Average meal intake, kg/event	C1HG	0.28 (0.06)	0.28 (0.06)	–0.01 (0.93)
	C1SG	0.12 (0.43)	0.06 (0.71)	–0.19 (0.20)
	C2HG	0.09 (0.54)	0.15 (0.29)	–0.01 (0.92)
	C2SG	0.07 (0.69)	0.19 (0.26)	0.07 (0.69)
	C2SF	0.14 (0.39)	0.00 (0.99)	0.08 (0.62)

[1]C1SG = cohort 1 steers, growing phase (n = 28); C1HG = cohort 1 heifers, growing phase (n = 29); C2HG = cohort 2 heifers, growing phase (n = 29); C2SG = cohort 2 steers, growing phase (n = 25); C2SF = cohort 2 steers, finishing phase (n = 25).

high ME_M EPD sired group consuming more feed during each meal event (AMINT; $P = 0.07$). There were no other differences in behaviors between high and low sire ME_M EPD progeny ($P > 0.10$).

DISCUSSION

Characterizing cattle populations using feeding behaviors could prove beneficial in predicting DMI and towards identifying underlying variations in feed efficiency. The current study has identified some of these quantifiable behavioral indicators.

Table 4. Spearman rank correlations for performance and feeding behaviors between growing and finishing phases in Red Angus steers (C2SG and C2SF[1])

Trait	r (P)
ADG[2]	0.10 (0.56)
DMI[2]	0.56 (<0.01)
Residual feed intake[2]	0.50 (0.01)
Bunk visit frequency, events/d	0.56 (<0.01)
Bunk visit duration, min/d	0.47 (<0.01)
Feed bout frequency, events/d	0.57 (<0.01)
Feed bout duration, min/d	0.47 (<0.01)
Meal frequency, events/d	0.55 (<0.01)
Meal duration, min/d	0.56 (<0.01)
Average meal intake, kg/event	0.52 (<0.01)

[1]C2SG = cohort 2 steers, growing phase (n = 38); C2SF = cohort 2 steers, finishing phase (n = 38).

[2]Correlations for ADG, DMI, and residual feed intake obtained from Welch et al. (2012).

In the present study, feeding duration behaviors (BVDUR and FBDUR) were most correlated with performance measures (ADG and DMI) in Red Angus cattle. Interestingly, these traits were only correlated in growing phase animals, suggesting either a diet effect (high concentrate vs. lower concentrate) or a stage of maturity effect. Feed bout duration and ADG was significantly correlated in heifers with a trend towards positive correlation in C1SG. This suggests that ADG increases as the time spent consuming feed (in bouts) increases. These results are in agreement with Kelly et al. (2010) noting a trend ($P < 0.10$) amongst a mixed population of steers and heifers. Our findings indicate Red Angus heifer ADG is characterized most by FBDUR, with some correlation shown for BVDUR.

Previous researchers have also found positive correlations of FBFREQ and ADG in steer populations (Montanholi et al., 2010). In the present study, however, FBFREQ and BVFREQ were negatively correlated with ADG in heifers.

Feed bout duration was correlated with DMI in all growing phase Red Angus groups. This may imply that FBDUR is dependent on diet components, as C2SF did not show this relationship. Current results indicate individual feed bouts are more indicative of DMI than MDUR. In previous studies (Kayser and Hill, 2013), we have also observed strong correlations between feeding duration behaviors (head down duration and head down duration per meal) in growing Angus and Hereford bulls (correlation coefficients in the range of $r = 0.34$–0.52, all $P < 0.0001$). However, results of the present study differ from those reported by Montanholi et al. (2010), who found significant correlations ($P < 0.01$) of time per meal and DMI.

Associations of meal traits and efficiency have been reported in literature (Schwartzkopf-Genswein et al., 2002;

Table 5. Effect of Red Angus sire maintenance energy (ME_M) EPD group on progeny feeding behaviors[1]

Behavior	High sire ME_M EPD group	Low sire ME_M EPD group	*P*
Bunk visit frequency, events/d	70.1 ± 1.87	68.6 ± 2.27	0.60
Bunk visit duration, min/d	143 ± 2.25	145 ± 2.73	0.58
Feed bout frequency, events/d	59.2 ± 1.59	56.9 ± 1.93	0.37
Feed bout duration, min/d	139 ± 2.19	141 ± 2.65	0.51
Meal frequency, events/d	11.7 ± 0.53	11.8 ± 0.64	0.89
Meal duration, min/d	228 ± 4.76	209 ± 5.77	0.01
Average meal intake, kg/event	1.55 ± 0.07	1.35 ± 0.09	0.07

[1]Mean ± SE; $n = 178$ total progeny, $n = 106$ high ME_M EPD sire group, and $n = 72$ low ME_M EPD sire group.

Nkrumah et al., 2007; Paddock et al., 2008; Bingham et al., 2009; Lancaster et al., 2009; Kayser and Hill, 2013), although the current study did not show significant correlations between meal traits and ADG or DMI or RFI. Values for MDUR during both the growing (206 to 236 min/d) and the finishing phase (148 to 158 min/d) were substantially higher than those reported by Lancaster et al. (2009; around 100 min/d), who reported behaviors and performance of young Angus bulls on a forage-based diet. The diet composition, animal BW, individual animal appetite, total population of animals per pen, and number of bunks available are variables that determine the time required for feed consumption (de Haer et al., 1993; Bingham et al., 2009). Therefore, multiple factors impact the scale and variability of this behavior and may limit its predictive ability.

Red Angus groups examined in the current study did not show correlations between feeding frequency behavior traits and RFI noted in previous studies. Significant correlations of RFI and BVFREQ in beef cattle of 0.18 and 0.50 have been reported (Robinson and Oddy, 2004; Basarab et al., 2007). Similarly, Nkrumah et al. (2007) found both phenotypic and genetic correlations of FBFREQ and RFI in Angus and Charolais sired cattle offered a high-concentrate diet.

In the present study, both BVDUR and FBDUR showed trends towards correlation with RFI in C1HG. Similar to C1HG, BVDUR and RFI tended toward correlation for C1SG and C2SG. These trends suggest that animals with higher RFI values (lower efficiency) visit the bunk and consume feed over a longer period. These relationships are not completely repeated in FBDUR. This implies time spent at the bunk without feed intake may have shifted the correlation. These trends are comparable to those observed in our previous studies of growing Angus and Hereford bulls for which head down duration and head down duration per meal were highly correlated with RFI (correlation coefficients in the range of r = 0.40 to 0.59, all $P < 0.0001$). Similarly, Schwartzkopf-Genswein et al. (2011) reported a study of steers through backgrounding and finishing phases with animals classified by G:F rather than RFI. These authors report that both BVFREQ and BVDUR showed trends in which inefficient animals tended to consume feed during longer duration bouts and more frequently, with groups differing significantly for BVFREQ during the finishing phase. Consistent with these observations, Golden et al. (2008) reported daily eating bouts that significantly differed between RFI efficiency groups in the first of 2 experiments and trended similarly in the second experiment.

In the present study, strong correlations between growing and finishing phase steer behaviors, DMI, and RFI provide evidence of the value of feeding behaviors in predicting DMI across the 2 phases. Feeding behaviors measured during the postweaning phase are also predictive of those during later stages of the life cycle. Relationships of growing and finishing phase efficiency have been noted in the literature (Archer et al., 1998). However, it is suggested that several underlying mechanisms are implied in driving the efficiency status of animals, such as variations in intake and digestion of feed, basal metabolism, activity, and thermoregulation (Herd and Arthur, 2009). Previous studies have noted effects of diet type and feeding period in beef steers, causing a reranking in feed efficiency (Durunna et al., 2011). Changes in efficiency and intake caused by diet (high vs. low concentrate) may be due to shifts in rumen pH and microbial population (Calsamiglia et al., 2008). A study by Black et al. (2013) examined relationships of RFI and performance of beef heifers during growth and as 3-yr-old lactating cows. Results from their study also suggest that the performance of animals classified as efficient during growth phase is reflected later in life as cow intakes ranked similarly. The encouraging data reported within our study suggesting the power of feeding behaviors in predicting DMI across life stages require further studies to determine whether there are breed-specific (or study-specific) elements of these relationships or whether they can be generalized.

Sire ME_M EPD effect on progeny behaviors provides insight that feeding behavior may have a genetic component. The ME_M requirement of an animal is an indicator of energy expenditure associated with sustaining body tissues (Ferrell and Jenkins, 1985). By reducing ME_M, it may be possible to reduce nutrient intake associated with maintenance and shift this towards gain. Correlations of MDUR and the trend of AMINT suggest that meal data may be most indicative of sire ME_M EPD effect as compared to other feeding behaviors observed in this study. These results are important as it has been implied that improved RFI may be associated with decreased ME_M requirements via more effective feed conversion (Richardson and Herd, 2004). The present study implies that sires with lower ME_M produce progeny with lower MDUR and possibly lower AMINT. As ME_M EPD is also positively associated with growth and size traits, it will be important to determine whether these factors are also related to MDUR and AMINT. These results suggest lower feed consumption of low ME_M EPD sire progeny. Therefore, these results imply the need for further analysis. Results from Welch et al. (2012) showed no relationship between of sire ME_M EPD and progeny phenotypic RFI. The relationship of ME_M and feeding behavior has not been examined to the authors' knowledge.

The use of feeding behaviors to predict DMI and efficiency in Red Angus cattle may have potential to predict all-of-life DMI, especially with respect to BVDUR and FBDUR behaviors. Such analysis may also provide additional insight into variation of phenotypic RFI. Correlations of behaviors across growing and finishing phase Red Angus steers suggest that behaviors are conserved and therefore may be useful for animal assessment outside of traditional (postweaning) test periods. Should these behaviors be shown to be predictive in a more general context, it is possible that the need to estimate individual animal intake in determining feed efficiency could be overcome. The equipment needed to measure individual BVDUR and FBDUR is less complex and less expensive than equipment needed to accurately measure individual animal DMI. However, the gold standard in measuring DMI will likely remain with actual measurements of DMI mass required well into the future.

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