Effects of timing and duration of test period and diet type on intake and feed efficiency in Charolais-sired cattle

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Introduction

Profitability, within all sectors of beef production, is a function of inputs and outputs. In production systems, individual feed consumption represents the greatest financial burden (Miller et al., 2001). However, a majority of the intake evaluations performed in beef cattle have been conducted in cattle fed grain-based diets rather than those grazing forages. Furthermore, regulation of feed intake is influenced largely by diet type; thus, there may be limitations of using feedlot intake information in heifer development systems. For example, intake of grain-based, high energy feeds is controlled metabolically or chemostatically (NRC, 1996), whereas when poor quality, roughage-based diets are fed, intestinal capacity, “gut-fill”, limits intake (Mertens, 1994). In addition, Durunna et al. (2011; 2012) discovered that feed efficiency reranking occurs in cattle fed different diet types at different biological stages. Therefore the regulation of feed intake of these different diet types may influence their efficiency of feed utilization, and some calves may be more efficient on different diet types.

Considering intake of forage and grain is regulated by different mechanisms, the hypothesis is that intake and efficiency will not be correlated across differing diet types, suggesting that feed intake and efficiency measures on differing diet types cannot be used interchangeably. We also hypothesize that intake evaluations can be shortened without losing accuracy; and feed efficiency can be measured at different stages of maturity in growing feedlot calves. This experiment has two objectives: 1) determine appropriate test length, timing, and repeatability of DMI, ADG, and efficiency over different biological time points; and 2) determine the relationship between forage-and grain-fed efficiency measures.

Materials and Methods

Two separate postweaning intake and performance evaluations were conducted on Charolais X SimAngus calves (*n* = 628; initial BW = 238 ± 46 kg, age = 211 ± 32 d). The 2 performance and intake tests represent the 2 major biological periods in the feedlot: growing and finishing. Upon arrival at the feedlot and prior to the growing period, steers were transitioned over 3 wk to a grain-based growing diet consisting of 50% corn, 15% corn co-products, 25% corn silage, and 10% supplement. Heifers were fed a forage-base diet consisting of 47.5% corn silage, 47.5% alfalfa haylage, and 5% supplement. After completion of the 70 d growing period, heifers were transitioned over 3 wk from the forage-based diet to the grain-based diet. All cattle were fed the common, grain-based diet for the 70 d finishing period.

Growing/Finishing Intake and Performance Data Collection

Upon arrival, cattle were stratified by sire and allotted to pens equipped with a GrowSafe® automated feeding system (Model 4000E, GrowSafe Systems Ltd., 86 Airdrie, Alberta, Canada) so individual intakes could be recorded. For each performance and intake test (growing and finishing) a minimum of 70-d were required each year to calculate individual animal ADG and DMI. This complies with Beef Improvement Federation (**BIF**) recommendations for performance data and intake collection (BIF, 2010). At the conclusion of the 70d finishing period test, individual feed intakes were no longer recorded using the GrowSafe system, as cattle were bunk fed for 60 ± 30 d until slaughter.

Performance data collection remained consistent for both years during both the growing and finishing performance tests. Initial and final BW for each test was the average of 2 consecutive d BW measurements prior to morning feeding. All cattle were weighed every 2 wk. Individual animal ADG was calculated by regressing each individual weight of all time points during both the growing and finishing evaluation period. Individual mid-test metabolic BW (**MW**) was determined by the linear regression coefficients for each animal for the growing and finishing evaluation period.

At the conclusion of each test period, 12th rib fat thickness was measured via ultrasound, to account for the variation in residual feed efficiency measures due to body composition. Ultrasound measurements were taken by trained personnel using an Aloka 500SV (Wallingford, CT) B-110 mode instrument equipped with a 3.5-Mhz general purpose transducer array. Twelfth rib fat thickness measurements were taken in transverse orientation between the 12th and 13th ribs approximately 10 cm distal from the midline. Images were analyzed using CPEC imaging software (Cattle Performance Enhancement Company LLC., Oakley, KS).

Total Intake Period Performance and Intake Data Collection

Individual feed intakes were recorded during the growing, transition, and finishing periods of this experiment for steers fed grain throughout the study; therefore, the combination of recorded individual DMI during these periods was identified as the 161-d total intake period DMI (**161DMI**). Initial and final BW represented the average of 2 consecutive days BW measurements during the growing and finishing periods, respectively. Individual animal ADG was calculated by regressing all weights taken over the course of the growing, transition, and finishing periods and was identified as (**161ADG**). One hundred sixty-one d total intake period mid-test metabolic BW (**161MMW**) was calculated using the ADG regression coefficients.

Total Feeding Period Performance Data Collection

For steers fed the grain-based diet during both test periods, performance was evaluated for the duration of time on feed from feedlot arrival to slaughter. This method was used to determine total feeding period BW gain. Initial BW represented the BW of calves at arrival at the feedlot (age = 180 ± 29 d). Individual final BW was calculated by dividing HCW by a standard dressing percentage of 63%. Two total feeding period performance measures were calculated to test the relationship between traditional and regressed measurements of performance during an animal's time on feed. Total feeding period ADG (**FPADG**) was calculated by the difference between initial and final BW, divided by the number of days between feedlot arrival and harvest. Regressed individual feeding period ADG (**R_FPADG**) was determined via regression of all weights taken from feedlot arrival to adjusted final BW.

Test Duration for DMI

To test the effects of intake evaluation period timing and duration, individual animal DMI during the growing period was divided into 10 total sections. Sections of intake during the growing period included: the final 7 d of intake (**70_63DMI**), the final 14 d of intake (**70_56DMI**), the final 21 d of intake (**70_49DMI**), the final 28 d of intake (**70_42DMI**), the final 35 d of intake (**70_35DMI**), the final 42 d of intake (**70_28DMI**), the final 49 d of intake (**70_21DMI**), the final 56 d of intake (**70_14DMI**), the final 63 d of intake (**70_7DMI**), and the final 70 d of intake (**70_0 DMI**).

Calculation of Feed Efficiency

Feed efficiency traits were determined for all cattle during the growing and finishing periods. Feed conversion ratio (**FCR**) represented the ratio of individual animal feed:gain, and was calculated by dividing individual average daily DMI by regressed ADG. Contemporary groups were assigned for each individual animal according to year born and sex. Individual animal residual feed intake (**RFI**) and residual BW gain (**RG**) were calculated for both growing and finishing periods. Residual feed intake was calculated using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC), and was assumed to represent the residuals of a multiple regression model regressing DMI on MW, ADG, and 12^{th} rib fat thickness using pen as a random effect. Likewise, RG was calculated using the PROC MIXED procedure of SAS, and was assumed to represent the residuals of a multiple regression model regressing ADG on DMI, MMW, and BF using pen as a random effect.

To test the concept of RFI using decoupled performance and DMI information, 35 d of recorded intake were evaluated along with FPADG as the measurement of individual animal BW gain, and mid-test BW was calculated by the average of calves' initial and final BW, raised to the 0.75 power. The 35 d of recorded intake evaluated in this measure of feed efficiency represented the first and final 35 d of each feeding period. Residual feed intake represented the residuals of a multiple regression equation regressing 35 d of recorded DMI on FPADG, feeding period mid-test metabolic weight, and carcass BF using pen as a random effect.

Statistical Analysis

Simple pearson correlations were calculated for ADG, DMI, and efficiency for the growing, finishing, 160-d total intake period, and total feeding periods using the PROC CORR procedure of SAS. Pearson correlations were used to test the number of days required for accurate DMI estimates using the PROC CORR procedure of SAS. All rho values were considered significant when $P \leq 0.05$. Correlations were considered strong when rho values were greater than or equal to 0.70; moderate when rho values were between 0.30 and 0.69; and weak when less than 0.29.

Results and Discussion

Relationships between grain-fed steer DMI, ADG and feed efficiency are presented in Table 1. Steers that consumed more feed during the growing period also had greater DMI during the finishing phase (r = 0.56; $P < 0.05$). The moderate association of DMI during the growing and finishing periods of this experiment reflects the results of Kelly et al. (2010), who reported a correlation of 0.61 between DMI when heifers were fed a 70:30 pelleted concentrate:corn silage diet during consecutive feeding periods. However, ADG was not repeatable in steers between the growing and finishing periods (r = 0.11; $P = 0.06$). Although this was a surprise, because DMI was repeatable and related to ADG in both periods, this phenomenon was also observed by Kelly et al. (2010); who also reported the same correlation of 0.11, and suggested that cattle ADG may re-rank compared to their contemporaries. Growing period RFI was moderately correlated (r = 0.63; $P < 0.05$) to finishing period RFI. Although RG during the growing period was correlated (r = 0.24; *P* < 0.05) to RG in the finishing period, the relationship was much weaker compared to RFI. Calculated FCR during the growing and finishing periods were also moderately correlated (r = 0.41; *P* < 0.05). The repeatability of these feed efficiency traits suggest that steers that had more desirable growing period feed efficiency were also more efficient during the finishing period.

Table 1. Simple phenotypic correlations between postweaning traits for steers fed grain[a]

Item	Grow DMI	Grow ADG	Grow RFI[1]	Grow RG[2]	Grow FCR[3]	Finish DMI	Finish ADG	Finish RFI[1]	Finish RG[2]	Finish FCR[3]
Grow DMI	**1**	**0.64**	**0.49**	0.00	**0.51**	**0.56**	-0.02	**0.27**	**-0.30**	**0.44**
Grow ADG		**1**	0.00	**0.71**	**-0.31**	**0.29**	0.11	-0.04	-0.04	0.11
Grow RFI[1]			**1**	**-0.42**	**0.59**	**0.38**	-0.06	**0.63**	**-0.39**	**0.34**
Grow RG[2]				**1**	**-0.76**	-0.04	**0.19**	**-0.28**	**0.24**	**-0.22**
Grow FCR[3]					**1**	**0.38**	**-0.13**	**0.37**	**-0.30**	**0.41**
Finish DMI						**1**	**0.49**	**0.66**	0.00	**0.22**
Finish ADG							**1**	0.00	**0.77**	**-0.72**
Finish RFI[1]								**1**	**-0.51**	**0.49**
Finish RG[2]									**1**	**-0.84**
Finish FCR[3]										**1**

[a] |R| values in bold are significant (*P* < 0.05)
[1] Residual feed intake
[2] Residual BW gain
[3] Feed conversion ratio expressed as feed:gain

The fact that ADG was not repeatable across test period was not expected. However, there were moderate associations (0.69 ≥ r ≥ 0.58; *P* < 0.05) between growing and finishing ADG when compared to R_FPADG and FPADG (Table 2). This suggests that regardless of timing of the evaluation of postweaning gain, both periods can serve as similar proxies in determining the performance of a growing animal during its entire time spent on feed. The stronger correlation (0.96 ≥ r ≥ 0.81; *P* < 0.05) between 161ADG and R_FPADG and FPADG suggests that longer periods of performance evaluation may result in more accurate determinations of ADG over an animal's entire lifespan. The strong, positive correlation (r = 0.85; *P* < 0.05) between R_FPADG and FPADG suggests that cattle performance may be accurately predicted by dividing the difference of an animal's final BW and feedlot arrival weight by the number of days on feed. This is important, because FPADG is a measure of performance that is widely accepted within the industry. When FPADG is calculated by dividing the difference between adjusted HCW and feedlot arrival BW by the number of d on feed, FPADG can be an effective proxy for individual ADG over the lifespan of calves, which is supported by Retallick et al. (2015).

Table 2. Simple phenotypic correlations between measurements of ADG during different feeding periods and biological timepoints[a]

Item	Growing	Finishing	161ADG[1]	R_FPADG[2]	FPADG[3]
Growing	**1**	0.11	**0.57**	**0.58**	**0.58**
Finishing		**1**	**0.76**	**0.69**	**0.58**
161ADG[1]			**1**	**0.96**	**0.81**
R_FPADG[2]				**1**	**0.85**
FPADG[3]					**1**

[a] |R| values in bold are significant ($P < 0.05$)
[1] 161 d intake period
[2] Total feeding period (regressed ADG)
[3] Total feeding period

As the number of recorded d of DMI increased, the association between number of d of recorded DMI and overall period DMI increased (Table 3). Due to a strong correlation of 0.95 ($P < 0.05$), this experiment suggests that only 35 d of recorded intake are sufficient for predicting 70d test period DMI. However, *when* DMI intake is recorded for those 35 d makes a difference. Recorded DMI during the end of the growing period was a more accurate predictor of DMI during the finishing period. This study showed that in order to accurately predict DMI across different time points in life, not only is it important to record a sufficient amount of d, but the proximity of the different test periods being compared is an important factor to consider as well.

Table 3. Simple phenotypic correlations during different durations of mean DMI observations from the end of the 70d growing period in grain fed steers[a]

Item	70-0DMI	FDMI[1]	161DMI[2]
70-63DMI	**0.88**	**0.58**	**0.86**
70-56DMI	**0.87**	**0.62**	**0.87**
70-49DMI	**0.89**	**0.62**	**0.88**
70-42DMI	**0.92**	**0.61**	**0.89**
70-35DMI	**0.95**	**0.61**	**0.90**
70-28DMI	**0.97**	**0.58**	**0.89**
70-21DMI	**0.98**	**0.56**	**0.89**
70-14DMI	**0.99**	**0.56**	**0.90**
70-7DMI	**1**	**0.56**	**0.90**
70-0DMI	**1**	**0.56**	**0.90**
FDMI[1]		**1**	**0.85**
161DMI[2]			**1**

[a] |R| values in bold are significant ($P < 0.05$)
[1] Finishing period DMI (d91-161DMI)
[2] 161 d intake period total DMI (d0-161DMI)

Minimal work has been done investigating the idea of decoupling performance and intake information when determining the feed efficiency of a feedlot steer during its entire time on feed. Interest in this concept is due to the fact that accurate measures of DMI and ADG require substantially different durations, and performance and intake evaluation tests are costly. Total beef production efficiency can be improved when a greater number of animals are tested annually; therefore, more cost effective ways to test growing animals are needed. In our trial, comparisons were made between RFI values using short duration intake test periods (35 d) with FPADG; and RFI measures calculated by the standards set forth by the BIF (Table 4). Relationships ranged from strong to weak ($0.85 \geq r \geq 0.28$; $P < 0.05$) between these measures of RFI using decoupled DMI and ADG and 70 d test period RFI. This suggests that there is a possibility that these alternative measurements of RFI may have efficacy to the industry and should be further investigated.

Table 4. Simple phenotypic correlations between measures of feed efficiency for grain fed steers during the growing, finishing, and total feeding period using decoupled DMI and ADG variables in the predicted DMI model in the total feeding period[a]

Item	Growing RFI[1]	Finishing RFI[1]
0-35RFI[2]	**0.70**	**0.28**
36-70RFI[3]	**0.54**	**0.62**
90-125RFI[4]	**0.56**	**0.85**
126-161RFI[5]	**0.46**	**0.79**

[a] |R| values in bold are significant ($P < 0.05$)
[1] Residual feed intake
[2] Total feeding period residual feed intake when predicted total feeding period DMI is a linear function of the first 35d of recorded DMI during the growing period, FPADG and mid-test metabolic BW, and carcass BF.
[3] Total feeding period residual feed intake when predicted total feeding period DMI is a linear function of the final 35d of recorded DMI during the growing period, FPADG and mid-test metabolic BW, and carcass BF.
[4] Total feeding period residual feed intake when predicted total feeding period DMI is a linear function of the first 35d of recorded DMI during the finishing period, FPADG and mid-test metabolic BW, and carcass BF.
[5] Total feeding period residual feed intake when predicted total feeding period DMI is a linear function of the final 35d of recorded DMI during the finishing period, FPADG and mid-test metabolic BW, and carcass BF.

Regulation of feed intake may differ when cattle are fed differing diet types, and DMI is related to energy content of the feed delivered (NRC, 1996) or physical fill. Since DMI plays a vital role in feed efficiency, mechanisms of intake regulation for divergent diet types may confound the accuracy of comparing RFI of cattle when fed grain or forage. Minimal research has been conducted comparing RFI values when cattle are fed differing diet types. Comparisons of feed intake and efficiency when two different diet types are fed are presented in Table 5. The correlation between forage and grain DMI was 0.58 ($P < 0.05$). This linear relationship of DMI closely parallels the relationship of DMI during the growing and finishing period of grain fed steers (0.56), and in this study, suggests mechanisms of intake regulation on these diet types may not differ. The moderate, positive correlation (r = 0.40; $P < 0.05$) between RFI values derived from forage and grain based diets suggested that growing cattle that were more efficient when fed forage were also more efficient when fed grain. This is an important discovery, as most feed intake and subsequent efficiency tests are done in feedlot-like test stations.

Table 5. Simple linear phenotypic correlations between postweaning traits in heifers fed different diets[a]

Item	Forage DMI	Forage ADG	Forage RFI[1]	Forage RG[2]	Forage FCR[3]	Grain DMI	Grain ADG	Grain RFI[1]	Grain RG[2]	Grain FCR[3]
Forage DMI	**1**	**0.25**	**0.69**	0.00	**0.24**	**0.58**	-0.01	**0.24**	**-0.26**	**0.43**
Forage ADG		**1**	0.00	**0.53**	**-0.72**	**0.16**	**-0.30**	-0.03	**-0.17**	**0.42**
Forage RFI[1]			**1**	**-0.29**	**0.39**	**0.25**	0.00	**0.40**	**-0.17**	**0.17**
Forage RG[2]				**1**	**-0.53**	-0.08	**-0.11**	**-0.15**	-0.10	0.05
Forage FCR[3]					**1**	**0.14**	**0.27**	**0.17**	0.06	**-0.16**
Grain DMI						**1**	**0.36**	**0.65**	0.00	**0.38**
Grain ADG							**1**	0.00	**0.82**	**-0.70**
Grain RFI[1]								**1**	**-0.36**	**0.46**
Grain RG[2]									**1**	**-0.79**
Grain FCR[3]										**1**

[a] |R| values in bold are significant ($P < 0.05$)

[1] Residual feed intake

[2] Residual BW gain

[3] Feed conversion ratio expressed as feed:gain

Conclusions

Relationships existed between measures of feed efficiency and intake across diet type and test period. Accurate feed efficiency measures can be obtained in either the growing or finishing period of feedlot cattle. The relationship of forage and grain DMI and efficiency in heifers suggests that measures of DMI and feed efficiency in heifers are relevant, regardless of diet fed. This suggests that DMI and efficiency information derived from the feedlot may have application to the cowherd. Limitations on test period length are due to the number of d to accurately assess individual ADG. Since intake evaluation periods can be shortened without losing accuracy in predicting individual animal DMI, decoupling performance from DMI information may be the most cost effective way to test a greater number of animals annually.

More research is needed to further investigate novel methods of testing for feed efficiency with the vision of improving beef production efficiency as a whole.

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