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Test Duration for Residual Feed Intake in Commercial Bulls

[1]Z. Wang , [2]J. A. Basarab, [2]L. A. Goonewardene, [3]D. H. Crews, Jr,
[4]P. Ramsey, [2]K.L. Lyle, [5]N. French, [1]E.K. Okine and [1]S.S. Moore
[1]Department of Agricultural, Food and Nutritional Science, University of Alberta,
Edmonton, Alberta, Canada T6G 2P5
[2]Alberta Agriculture, Food and Rural Development, Western Forage Beef Group,
Lacombe Research Centre, 6000 C and E Trail, Lacombe, Alberta, Canada T4L 1W1
[3]Agriculture and Agri-Food Canada Research Centre, 5403-1st Avenue South,
Lethbridge, Alberta, Canada T1J 4B1
[4]Alberta Agriculture, Food and Rural Development, Main Floor, Provincial Building,
129 - 4 Avenue W., High River, Alberta, Canada T1V 1M6
[5]Olds College, 4500-50th street, Olds, Alberta, Canada T4H 1R6

Abstract: The objective of the study was to identify the optimum test duration for Residual Feed Intake (RFI) in two contemporary groups of commercial beef cattle. Thirty British and 46 Continental beef bulls were placed in two adjacent pens each fitted with the GrowSafe® System for measuring individual animal feed intake. The test period was 112 days and the test diet consisted of 77.0% barley silage, 20.0% steam rolled barley and 3.0% beef supplement (32% crude protein). The variance in RFI at 70 days on-test was 0.27 and remained relatively unchanged to 112 d in the Continental bulls. The optimum test duration based on a break point analysis was 82.6 and 69.5 days for British and Continental bulls respectively. The Pearson (simple) and Spearman (rank) correlations for RFI at 70, 84 and 96-d with 112-d increased as the bulls approached the end-of-test at 112-d in both groups but the correlations were stronger in the Continental compared with the British bulls. A 70-84 day test with weights taken every two weeks preceded by a 28-day adjustment was adequate to get a reliable estimate of RFI in commercial bulls of both contemporary groups under Canadian winter conditions. The cost of feed required for 42-d can be saved in Continental bulls by shortening the testing time and this amounts to an average of 17.7 kg/head/day of feed on-test and many more bulls can be tested for RFI each year.

Key words: Residual feed intake, test duration, contemporary group, commercial bulls

INTRODUCTION

The cost of feed affects the profitability of commercial beef operations. A 5% improvement in feed efficiency could have an economic impact four times greater than a 5% improvement in average daily gain[1]. Thus improvements in feed efficiency will have a large influence on the cost of production, as it is moderately heritable[2,3]. Residual Feed Intake (RFI) or net feed intake is recognized as a better method of measuring feed efficiency since it is independent of on-test weight gain and body weight[2-4]. RFI is defined as the difference between an animal's actual feed intake and its expected feed requirements for maintenance and growth. Thus, it measures the variation in feed intake that remains after the requirements for maintenance and growth have been removed. Since RFI is moderately heritable ($0.35<h^2<0.49$), it has been used as a criterion to select breeding stock in tests that have facilities to record individual feed intakes and testing periods of between 70-150 days have been reported in the literature[5,6]. A 140-day test is considered an industry standard for testing bulls for rate of gain in North America[7,8], but many organized bull tests have been reduced to 112 d. However, Archer *et al.*[9] and Archer and Bergh[5] suggested that a 70-84 day test was adequate to get an accurate measure of RFI in sires of British breeds and other biological types. These recommendations were based on the change in genetic and phenotypic variances over-time, phenotypic and genetic correlations, and efficiency of selection. If the testing time can be shortened while maintaining the same degree of accuracy, by correctly classifying animals into their respective (positive or negative) RFI categories with inimal rank changes, then on-test feeding costs may be

Corresponding Author: L. A. Goonewardene, Alberta Agriculture, Food and Rural Development, Western Forage Beef Group, Lacombe Research Centre, 6000 C and E Trail, Lacombe, Alberta, Canada T4L 1W1
Tel: +1 780 427 4545., Fax: +1 780 427 1057

reduced. Although many studies have addressed the duration of performance tests for growth rate and feed efficiency, there are only a few studies[7,9] addressing the duration of testing for RFI. There is little information on the relationship between RFI during early and late testing periods or the ranking and rank change among animals during the test period North America. The objective of this study was to determine if end-of-test RFI is correlated with RFI's calculated prior to the end-of-test and ascertain an optimum test duration for RFI in commercial bulls of two contemporary groups.

MATERIALS AND MATHODS

In early October of 2003, 76 spring born bull calves arrived at the Olds College feed intake facility, Olds, Alberta, Canada. They weighed 342.0 kg (SD = 44.7) and were 240 (SD = 17) days of age.

All animals had been vaccinated for Infectious Bovine Rhinotracheitis, Parainfluenza3, Bovine Viral Diarrhea, Bovine Respiratory Syncytial Virus, *Haemophilus somnus*, *Pasteurella multocida* and clostridial diseases two to four weeks before arriving at the experimental facility. Upon arrival, each bull was re-vaccinated, treated with a pour-on parasiticide and individually identified by inserting a radio frequency transponder button into its right, or left ear, opposite the ear with the animal's tattoo. The transponder button was located five to six cm from the base of the ear, in the middle, with the transponder button on the inside part of the ear. The GrowSafe® system recognized each bull by its transponder.

Two contemporary groups, British (Angus and Hereford) and Continental (Charolais, Simmental and Limousin) bulls were separated into two adjacent pens due to differences in body size and acclimated to feeding from the GrowSafe® System over a 28-day adjustment period. The bulls started on a diet consisting of 15% alfalfa-grass hay, 71.9% barley silage, 10% barley grain, 3% (32-18) feedlot supplement and 0.1% 18:18 mineral (as-fed basis) and were fed *ad libitum*. On Day-7 of the adjustment period, the hay was reduced to 7%, silage increased to 75.9%, and barley increased to 14% along with 3% supplement and 0.1% 18:18 mineral. On day-14, the hay was removed and the barley silage increased to 79.9%. The amount of barley was increased to 17% with supplement and mineral levels remaining at 3% and 0.1%, respectively. The amount of barley in the diet increased until the bulls were adjusted to a test diet consisting of 23.0% concentrate (as fed basis) by the end of the adjustment period (Table 1). The adjustment period was followed by a 112-day test period. Wood chips and shavings were used as bedding and were placed into the pen as required. Samples of the total mixed test diet were collected weekly, pooled and analyzed monthly. Monthly samples of the diet were analyzed for % Dry Matter (DM) by drying a sample at 100 °C in a forced-air oven to a constant weight. Organic matter was determined by ashing a dried sample at 550 °C[11]. The calcium and phosphorus contents of the samples were also determined[10]. Nitrogen (N) content was determined by Kjeldahl [11]. Crude protein was calculated as 6.25 x N. Neutral detergent fibre, acid detergent fibre and lignin were determined by the procedure of Robertson and Van Soest [13]. Bulls were weighed on 0, 14, 28, 42, 56, 70, 84, 98, and 112-day and cumulative feed intakes obtained at 14, 28, 42, 56, 70, 84, 98 and 112-day on-test using the Growsafe® System. All animals in this study were cared for under the guidelines established by the Canadian Council on Animal Care[14].

The growth of the 76 bulls on test was modeled by the linear regression of weight on days on-test with following model:

$$wt_{it} = a_{it+} + b_{it}x_t + e_{it}$$

where, wt_{it} is the observed body weight of animal i at time t, a_{it} is the estimated initial body weight of animal i at time t, b_{it} estimated regression coefficient which is the estimated average daily gain of animal i at time t, x_t is the days on-test at time t, and e_{it} is residual error associated with observed body weight wt_{it}.

The high R^2 values (0.90-0.98) also indicated that growth during this phase of the animal's life was linear and that the choice of a linear regression model was appropriate. Initial body weight and average daily gain for each individual animal obtained from the above equation were used to estimate the Mid-Body Weight (MIDWT) as follows:

$$MIDWT_{it} = a_{it} + (b_{it})(t/2)$$

where, $MIDWT_{it}$ is the estimated mid-point body weight of animal i at time t ,a_{it} is the initial body weight, is the estimated average daily gain of animal i at time , and t is number of days on-test.

Total feed intake of each animal at a specified test duration was converted to total DM intake (46.07% DM in diet), and then to total energy intake by multiplying total DM intake by 11.05 MJ ME/kg DM. Total energy intake was then divided by 10 to give total DM intake standardized to an energy density of 10 MJ ME/kg DM. This value was then converted back to total standardized feed intake by dividing total standardized DM intake by

0.4607. Total standardized feed intake was then divided by the number of days on test to give average standardized daily feed intake (SFI, kg/day). To calculate expected feed intake (EFI, kg/day), ADG (kg/day) and metabolic MIDWT ($kg^{0.75}$) were used to model daily SFI[3,9]. A separate model was fitted for each contemporary group within test day (14 to 112-d) using the GLM procedure of SAS[15]. The model fitted was:

$$y_i = a_i + b_{i1}x_{i1} + b_{i2}x_{i2} + e_i,$$

where, y_i is observed daily SFI for animal i, a is the intercept for individual i, b_{i1} is the partial regression coefficient of SFI on average daily gain of individual i, b_{i2} is the partial regression coefficient of SFI on metabolic mid-weight of individual i, and e_i is the residual error associated with SFI of animal i, x_{i1} is observed ADG and x_{i2} is observed MIDWT for animal i. This resulted in 16 equations that were used to calculate EFI for animals within contemporary day and test day. Residual feed intake was then calculated at 14, 28, 42, 56, 70, 84, 98 and 112-day on-test, as the deviation of SFI from EFI (RFI = SFI - EFI).

The criteria used to determine the optimum test duration were change in the phenotypic variances of RFI over-time, Pearson (simple) and Spearman (rank) correlations of RFI between the different days on test. The analyses were done separately for each contemporary group. The MIXED model procedure[15] was used to perform a repeated measures analysis of variance with the following model:

$$RFI_{ijt} = \mu + \beta_j + \gamma_t + (\beta\gamma)_{jt} + \alpha_{i(j)} + e_{ijt}$$
$$E(RFI_{ijt}) = \mu + \beta_j + \gamma_t + (\beta\gamma)_{jt}$$
$$Var(RFI_{ijt}) = v_{ji}$$

where, RFI_{ijt} is the estimated residual feed intake of animal i of contemporary group *j* at time t, μ is the fixed overall mean effect, β_j is the fixed jth contemporary group effect (British and Continental), γ_t is the fixed t^{th} test day effect (14, 28, 42, 56, 70, 84, 98 and 112-d), $(\beta\gamma)_{jt}$ is the fixed interaction effect of j^{th} contemporary group with t^{th} test day, $\alpha_{i(j)}$ is the random effect of ith animal within jth contemporary group, e_{ijt} is a random residual error associated with RFI_{ijt}, v_{ji} is the block diagonal covariance matrix associated with animal i and contemporary group j. The first order ante dependence (ANTE(1)) covariance model was chosen for this analysis because the model fitted the data best. This decision was based on Schwarz's Bayesian information criterion. The Kenward-Roger method was used to determine denominator degrees of freedom. The variance/covariance matrix of the best fitting model provided measures of the change in variance over time on-test for each contemporary group. A break point analysis was done for each contemporary group using two-phase regression[17] to determine the point at which the slope of the variance changed in relation to the days on-test. The dependent variable for this analysis was the variance at each test day. Pearson and Spearman correlations were obtained between 14, 28, 42, 56, 70, 84, 98 and 112 day for RFI on-test using the correlation procedure[15] for each contemporary group.

RESULTS

Means and Standard Deviations for age, weight, growth and efficiency traits for British and Continental commercial bulls during the 112-day test are shown in Table 2. No differences ($p>0.05$) were observed for RFI between contemporary groups, time on-test and interaction, and all means for RFI were zero. The variances of RFI at each test day (14, 28, 42, 56, 70, 84, 96 and 112-day–on diagonal), Pearson (above diagonal) and Spearman (below diagonal) correlations are shown in Table 3and 4 for the British and Continental groups respectively. Among the British group, a noticeable decrease in the phenotypic variance was apparent up to 84 days on-test and the variance change was more

Table 3: Phenotypic variances (on diagonal), Pearson correlations (above diagonal) and Spearman rank correlations (below diagonal) of residual feed intake over 112 days on test in British bulls

	Days							
Days on test	14	28	42	56	70	84	98	112
14	0.58	0.81	0.77	0.75	0.73	0.7	0.67	0.64
28	0.78	0.33	0.94	0.92	0.9	0.86	0.82	0.79
42	0.72	0.91	0.27	0.98	0.96	0.91	0.87	0.84
56	0.68	0.87	0.95	0.23	0.98	0.93	0.89	0.86
70	0.64	0.83	0.91	0.98	0.19	0.95	0.91	0.88
84	0.57	0.73	0.85	0.9	0.93	0.17	0.96	0.92
98	0.54	0.69	0.77	0.85	0.9	0.95	0.15	0.96
112	0.38	0.49	0.59	0.7	0.77	0.87	0.95	0.14

All correlations are different from zero ($p<0.05$)

Table 4: Phenotypic variances (on diagonal), Pearson correlations (above diagonal) and Spearman rank correlations (below diagonal) of residual feed intake over 112 days on test in Continental bulls

	Days							
Days on test	14	28	42	56	70	84	98	112
14	0.83	0.89	0.83	0.81	0.82	0.79	0.78	0.77
28	0.86	0.77	0.97	0.94	0.92	0.9	0.88	0.86
42	0.8	0.93	0.55	0.96	0.95	0.92	0.9	0.89
56	0.76	0.84	0.94	0.36	0.98	0.96	0.93	0.92
70	0.73	0.77	0.88	0.97	0.27	0.98	0.95	0.94
84	0.71	0.75	0.83	0.92	0.97	0.27	0.98	0.96
98	0.7	0.71	0.79	0.89	0.95	0.98	0.29	0.99
112	0.69	0.67	0.76	0.85	0.92	0.96	0.99	0.3

All correlations are different from zero ($p<0.01$)

gradual from 84-112 days on-test. The break point for British bulls was 82.6 days. In the Continental bulls there was little change in the phenotypic variance for RFI beyond 70 days on-test. The break point for Continental bulls was 69.5 days. Thus, a 70-84-day test period for RFI in commercial British and Continental type bulls is deemed adequate to get a reliable estimate of RFI. Furthermore, the Pearson and rank corrrelations between the end-of-test RFI (112-day) and the preceding periods on-test (14 to 98-day) increased over time in both groups. However, between each test day and 112-d on test the Pearson and rank correlations were slightly higher in the Continental (range: Pearson r=0.77 to 0.99; rank r=0.69 to 0.99) compared to British (range: Pearson r=0.64 to 0.96; rank r=0.38 to 0.95). The rank correlations for RFI at 70, 84 and 98 days were highly correlated with the ranking at the end of the test 112-day, (r=0.92, 0.96 and 0.99 respectively) suggesting that animal rankings did not change much after 70 days on-test in the Continental group. In the British bulls the rank correations between 70, 84 and 98 with 112-day were 0.77, 0.87 and 0.95; respectively. Hence the rank correlation at 70-d with 112-d was stronger in the Continental bulls.

DISCUSSION

The result of present study indicated that the phenotypic correlations between 70, 84 and 96-day RFI with 112-day RFI were 0.88, 0.92 and 0.96, respectively for the British and 0.94, 0.96 and 0.99, respectively for the Continental bulls. These values are similar to the correlations of 0.93 and 0.83 obtained between 84-d and 105-d residual metabolizable energy intake (RMEI-which RFI expressed as metabolozable energy) in steers fed a 30% barley grain + 70% alfalfa silage and a 30% barley grain + 70% fenugreek silage diet respectively[17]. The phenotypic correlation of 0.94 between 70-d and 112-d for RFI in the Continental bulls in our study also compares well with the phenotypic correlation of 0.91 for RFI between 70-d and 119-d reported by Archer *et al.*[9]

Although many North American studies have addressed the duration of testing for gain in cattle, only three studies have been reported on the optimum test duration needed to get a reliable measurement of RFI or RMEI[4,17]. Of the three studies, one used data from Australia[9] the other from South Africa[6] and the third from Alberta, Canada[17]. All three studies were conducted under different conditions. It is therefore necessary to determine optimum test duration under different cattle management styles, test facilities, diets and environments so that the RFI concept can be adopted globally. For example, in the Australian study[9], cattle were fed a high forage diet, weighed at 14 day intervals, the rate of gain based on a growth curve (regression), and the study conducted in a research facility. In the North American study[17], steers were on six forage or forage plus grain diets with 10 steers per diet and weighed every 28 days. Present study was conducted in two contemporary groups in a research facility, and bulls were weighed at 14-d intervals using an electronic system, initial weight, rate of gain mid body weight calculated using a regression approach, precise dry matter intakes determined daily and composited every 14 days using the GrowSafe® system and bulls fed a diet containing 77% silage, 20% rolled barley grain and 3% protein supplement. There is some evidence to indicate that test duration for RMEI may be diet dependent, and that in a forage based (silage) diet RMEI test duration may be reduced to 60 from 84 days[17]. Moreover, our study was conducted between November and February that are the coldest winter months and the rate of gain, body weight and especially dry matter intake are all influenced by ambient temperature. Also, as RFI is an index that is adjusted for on-test rate of gain and weight, accurate measurements on gain, weight and especially dry matter intake become critical in obtaining reliable estimates of RFI.

There is some evidence in this study to suggest that slight differences in on-test duration for RFI may exist between the two contemporary groups. In the British group the 84-day test duration required to get a reliable

estimate of RFI is similar to the study reported by Goonewardene *et al*.[17] for RMEI in steers fed forage-grain diets. However, there were less British bulls (n=30) evaluated compared to Continental bulls (n=46). Hence one reason for the greater fluctuation in the phenotypic variance and less positive correlations towards the end-of-test in this group may be the small size of sample. Therefore, at least in the British bulls these results are considered preliminary.

Three approaches were used to obtain a reliable estimate of the days on test needed to get estimates of RFI. These were variance reduction, Pearson and Spearman rank correlations over-time, and all three approaches were complementary to one another. Moreover, similar results were obtained when the approaches were applied to the British and Continental bull data. However, when correlations are calculated in overlapping periods, as is the case in our study, there is a tendency for the correlations to be higher towards the end-of-test due to auto correlation. However, the decisions based on the reduction in variance and rank correlations over-time are not affected by auto correlation.

CONCLUSIONS

A 70-day test where cattle weighed every 14 days and preceded by a 28-day adjustment was adequate to get a reliable estimate of RFI in Continental bulls, fed a diet containing 75% silage and 30% grain, under Canadian winter conditions. In British types the optimum test duration for RFI appears to be around 84 days. The results on RFI test duration on commercial bulls agree with the findings of and Archer and Bergh[6] who recommended a test between 70-84 days. It also suggests that feed requirements for 42 days can be saved when the testing time is reduced to 70 from 112 days in Continental bulls. This amounts to an average saving of 17.7±1.8 kg/head/day of feed on-test. Furthermore, by shortening testing times many more bulls can be tested for RFI each year.

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