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ARTICLE

# Optimizing feed intake recording and feed efficiency estimation to increase the rate of genetic gain for feed efficiency in beef cattle

G. Manafiazar, J.A. Basarab, L. McKeown, J. Stewart-Smith, V. Baron, M.D. MacNeil, and G. Plastow



**Abstract:** Data from a total of 4842 animals were used to test whether the regular dry matter intake (DMI) data collection and residual feed intake (RFI) estimation period could be decreased. Eighty-three shortened test periods were compared with the regular test period, and the results showed that the DMI data collection period could be decreased to 42 d without significantly compromising accuracy of feed efficiency testing. Competency of the selected shorter period (42 d with 30–42 d of valid feed intake days) to predict regular test period DMI (84 d with 60–84 d of valid feed intake days) was tested using a set of agreements criteria. The results showed that the selected shorter period can be used to accurately and precisely predict regular test DMI. The selected shorter test period combined with regular body weight measurements were used to estimate RFI adjusted for backfat ($RFI_{fat}$). Assessment of agreement between estimated values for $RFI_{fat}$ showed that a shorter DMI test could be used to predict $RFI_{fat}$ with only 7% outside the range prediction. It is concluded that shortening the feed intake period to 42 d from 84 d could substantially increase power-of-the-test for experiments that target feed intake or efficiency and reduce per head cost with the current infrastructure.

*Key words:* beef cattle, feed intake test, residual feed intake, short period.

**Résumé :** Les données provenant d'un total de 4842 animaux ont été utilisées pour tester si la période de collecte des données d'ingestion de matières sèches (DMI — « dry matter intake ») et d'estimation d'ingestion d'aliments résiduels (RFI — « residual feed intake ») pouvait être diminuée. Quatre-vingt-trois périodes raccourcies de tests ont été comparées à la période habituelle de test et les résultats ont montré que la période de collecte de données de DMI pouvait être raccourcie à 42 j sans compromettre la précision des tests d'efficience alimentaire de façon significative. La compétence de la période raccourcie choisie (42 j avec 30 à 42 j d'ingestion valides d'aliments) pour prédire le DMI de la période ordinaire de test (84 j avec 60 à 84 j d'ingestion valide d'aliments) a été évaluée selon un ensemble de critères d'entente. Les résultats démontrent que la période plus courte choisie peut être utilisée pour prédire de façon précise et exacte les DMI ordinaires de tests. La période raccourcie choisie de test combinée aux mesures régulières de poids corporel a été utilisée pour prévoir la RFI ajustée pour le gras dorsal ($RFI_{fat}$). L'évaluation de l'entente entre les valeurs estimées de $RFI_{fat}$ a montré qu'un test DMI raccourci peut être utilisé pour prévoir la $RFI_{fat}$ avec seulement 7 % des valeurs en dehors de la plage de prédiction. Il est donc conclu que raccourcir la période de collecte de données d'ingestion d'aliments de 84 à 42 j peut augmenter la puissance du test de façon importante pour les expériences qui visent l'ingestion ou l'efficience d'aliments tout en réduisant les coûts par tête avec l'infrastructure actuelle. [Traduit par la Rédaction]

*Mots-clés :* bœufs de boucherie, test d'ingestion d'aliments, RFI, période raccourcit.

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**G. Manafiazar.** Department of Agricultural Food and Nutritional Science, University of Alberta, Edmonton, AB T6G 2P5, Canada; BeefBooster Inc., Calgary, AB T1Y 5E4, Canada.

**J.A. Basarab.** Department of Agricultural Food and Nutritional Science, University of Alberta, Edmonton, AB T6G 2P5, Canada; Alberta Agriculture and Forestry, Lacombe Research Centre, Lacombe, AB T4L 1W1, Canada.

**L. McKeown and G. Plastow.** Department of Agricultural Food and Nutritional Science, University of Alberta, Edmonton, AB T6G 2P5, Canada.

**J. Stewart-Smith.** BeefBooster Inc., Calgary, AB T1Y 5E4, Canada.

**V. Baron.** Agriculture and Agri-Food Canada, Lacombe Research Centre, Lacombe, AB T4L 1W1, Canada.

**M.D. MacNeil.** Delta G, Miles City, MT 59301, USA; Department of Animal, Wildlife and Grassland Sciences, University of the Free State, Bloemfontein 9301, South Africa.

**Corresponding author:** John A. Basarab (email: john.basarab@gov.ab.ca).

## Introduction

Feed cost is the single largest expense in beef production and accounts for 55%–75% of the total costs of calf-to-beef production systems [National Research Council (NRC) 2000; Alberta Agriculture and Rural Development (AARD) 2005]. Therefore, there is great interest to include feed intake and feed efficiency traits within the selection index [Beef Improvement Federation (BIF) 2010]. Some of the beef cattle breed associations such as the American Angus Association and American Gelbvieh Association are already using estimated dry matter intake (DMI) in their national cattle evaluation system (Culbertson et al. 2015), and there are many Central Test Stations measuring feed intake, and calculating feed efficiency traits including residual feed intake (RFI). Yet, it is difficult for these traits to be adopted by the entire beef industry and to be included in national selection indexes because of the high cost involved in individual data collection as well as insufficient infrastructure for feed intake recording.

Currently, individual feed intakes are recorded daily and body weights (BWs) are recorded every 14–28 d on growing animals for periods of 76–120 d following a 21 d adaptation period during their growth phase to test for RFI (Wang et al. 2006; BIF 2010; Culbertson et al. 2015). Residual feed intake is feed intake adjusted for mid-test metabolic body weight (MTMBW) and average daily gain (ADG), and more recently has been adjusted for final off-test backfat thickness ($RFI_{fat}$). Off-test backfat thickness accounts for 2%–5% of variation in feed intake, and adjusting for off-test backfat thickness makes $RFI_{fat}$ independent of body composition in feeder cattle (Basarab et al. 2003) and body fatness in replacement heifer (Basarab et al. 2011). Shortening the feed intake data collection period could reduce cost of the test, increases number of animals tested, and makes it possible to apply greater selection intensity. Several research groups (Archer et al. 1997; Wang et al. 2006; Culbertson et al. 2015) previously analyzed shortened feed intake test periods and concluded that the feed intake collection period could be shortened to 35–42 d (Archer et al. 1997; Wang et al. 2006; Culbertson et al. 2015). However, they also suggested that a longer period of 56 d (Culbertson et al. 2015), 63 d (Wang et al. 2006), and 70 d (Archer et al. 1997) was required for the RFI test without compromising accuracy of measurement. The greater duration of test was required when calculating RFI because a longer period was required to accurately measure the animals' growth. Existing reports on shortening DMI recording used data from bulls (Archer et al. 1997; Culbertson et al. 2015) and replacement heifers (Archer et al. 1997; Wang et al. 2006; Culbertson et al. 2015) with a maximum number of 760 animals generated from research stations. Besides their sample size, the data generated for research purposes could have lower error compared with commercial herds, and the data did not include feeder animals.

Culbertson et al. (2015) concluded that the measurement of efficiency is not limited by the length of the feed intake collection period. Instead, it is restricted by the time required for growth rate measurements (e.g., 76 d). This issue could be overcome by uncoupling DMI from growth rate such that feed intake could be measured over a shorter period (e.g., first 42 d) and growth rate measured over a longer period (e.g., 76 d or longer) provided that diet composition was kept constant over the full growth rate feeding period (Culbertson et al. 2015); this idea has not yet been tested. Therefore, the first objective of this research was to analyze feed intake data from combined commercial and research herds including bulls, replacement heifers, and feeders on a daily basis rather than weekly as used in the previous research, to find the minimum number of days required to have accurate DMI observations. Then as a second objective, we assessed reliability of DMI data from the selected shorter periods in combination with regular BW measurements to predict regular test DMI and $RFI_{fat}$.

## Materials and Methods

All animals were cared for in accordance with the guideline of the Canadian Council on Animal Care (1993).

### Data acquisition and animals

Data were extracted from the Phenomic Gap database (Crowley et al. 2014; Akanno et al. 2015; Lu et al. 2016), which contains information from feed efficiency trials conducted for research and commercial purposes at the Roy Berg Kinsella Research Ranch, Agriculture and Agri-Food Canada Lacombe Research and Development Center, Olds College, and various commercial feedlots in Alberta, Canada, from 2000 to 2015. The extracted data contained individual daily feed intake, body weight records at the start and end of test and every 14–28 d while on test. The dataset also had final backfat thickness, and diet ingredient composition and dry matter (DM; %) and metabolizable energy (ME; MJ $kg^{-1}$ DM) content. Parts of these data were used previously in numerous publications (e.g., Basarab et al. 2003, 2011; Manafiazar et al. 2015). The dataset consisted of 387 492 daily feed intakes from 2 066 bulls, 1 011 replacement heifers, and 2 078 feeder heifers, and steers making a total of 5 155 animals in 85 contemporary groups (CGs). A CG was defined as a group of animals in the same drylot pen with the same gender, physiological status, similar age (BIF guidelines recommends under 90 d range in age while the range in our CG was 60 d or less), and fed the same diet under the same management conditions. Animals without final backfat measurements ($n = 93$) or daily feed intake observations with absolute values greater or smaller than three standard deviations from the CG mean ($n = 220$) were excluded from analysis.

After this data editing, a total of 4842 animals (1917 bulls in 42 CG; 1972 feeders in 27 CG; and 953 replacement heifers in 16 CG) remained for analysis. Diet compositions and details of feed test procedures were previously described by Basarab et al. (2003, 2011) and Manafiazar et al. (2015). In short, each animal was tagged with a half-duplex radio frequency identification (RFID) tag, and daily individual feed intake data were recorded by the GrowSafe system (GrowSafe Systems Inc., Airdrie, AB, Canada). The GrowSafe System records animal RFID, bunk number, and bunk weight every second, and these data were used to calculate individual daily feed intake and are described in detail by Basarab et al. (2003).

**Test periods and statistical analysis**

Eighty-three shortened test periods were designed based on 1 d increments from day 0 to day 83, and one full test period, as a regular test, was considered from day 0 to day 84 to find the minimum required days to record DMI without compromising accuracy of feed intake and feed efficiency testing. Gross mean of DMI for an individual animal was calculated as the sum of DMI in each test period divided by the number of days on test within each test period. Then, mean and standard deviation of DMI were calculated across and by animal type for each test period. Relative percentage change of variance was considered as the difference between the variance of a shortened test period and the regular period divided by the variance of regular test period multiplied by 100. Pearson and Spearman correlations were performed between DMI of each shortened test period with the regular test period by CORR procedure in SAS (SAS Institute, Inc. 2013) across and by animal type. The GLM procedure in SAS was used to regress the regular test DMI on DMI of the shorter test periods to calculate the regression equation coefficient, and they were considered as efficiency indications of shortened period compared with regular test period (Culbertson et al. 2015) considering animal type as a class effect and CG as a fixed effect. The minimum required test days to obtain an accurate DMI measurement were selected by considering relative percentage change of variance, regression coefficient, and Pearson and Spearman correlation coefficients.

To test our second objective, a selected test period for DMI (42 d with 30–42 d valid feed intake) in combination with regular growth data (body weight records at the start and end of test and every 14–28 d while on test) and final backfat measurements were used to calculate $RFI_{fat}$. Practically, it is not feasible to have exactly 42 and 84 observations as shortened and regular test period, respectively, for all animals. It must also be stressed that when conducting a shorter duration DMI test (e.g., 42 d) automated feed intake equipment and standard operating procedures must be operating at high efficiency as few days can be lost (<5 d) due to equipment malfunction, power outage, and harsh weather. Therefore, we considered shortened test period as 30–42 observations within 42 d on test (42 d), and the regular test period was considered as 60–84 observations within 84 d on test (84 d). The average numbers of days with feed intake data were 39 and 73, respectively, for short and regular test period in our study. We also made sure that the same animals were included in both periods. These practice removed some of the animals resulting in 4672 animals in the analysis (1750 bulls, 960 replacement heifers, and 1962 feeders). The details of growth curve modeling and $RFI_{fat}$ calculation have been previously described by Basarab et al. (2003, 2011) and Manafiazar et al. (2015). In summary, daily feed intakes for each animal were averaged and converted to DMI using the DM% of the diet within CG. Average DMI was then multiplied by the diet ME (MJ kg$^{-1}$ DM) within CG then divided by 10 MJ kg$^{-1}$ DM (diets for replacement heifers and bulls) or 12 MJ kg$^{-1}$ DM (diets for feeder cattle) to calculate standardized dry matter intake (SDMI) to make the results comparable with other research reports. An individual growth curve for each animal was modeled by linear regression of observed BW against days on test to estimate animals' ADG and initial BW on test. Initial BW and ADG were used to calculate mid-test BW, and mid-test BW was raised to the power of 0.75 to obtain mid-test metabolic BW (MTMBW). Linear regression of observed average daily SDMI on ADG, MTMBW, and off-test backfat was used to calculate $RFI_{fat}$ within CG.

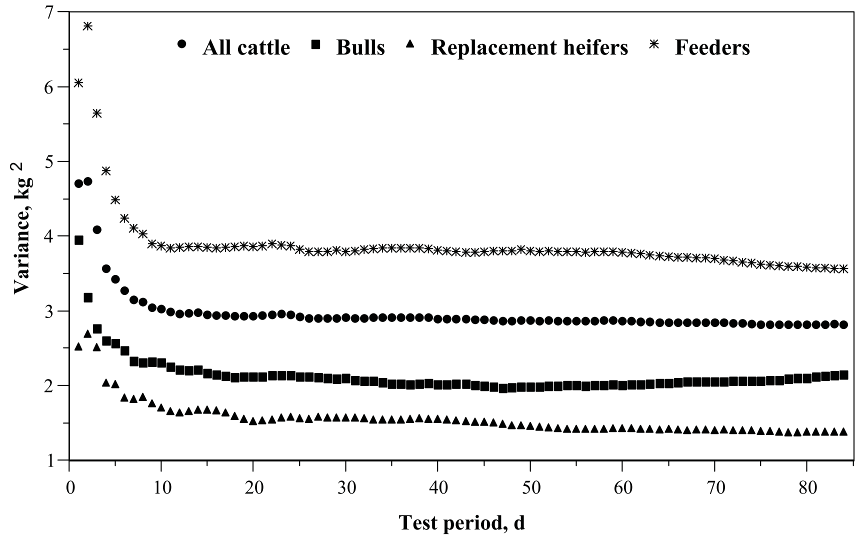
**Competency of a selected short period of measuring DMI to predict regular DMI and $RFI_{fat}$**

The selected shortened test period DMI (42 d with 30–42 d valid feed intake) was used to predict regular test (84 d with 60–84 d valid feed intake days) DMI and in combination with regular BW data predict $RFI_{fat}$. Compatibility of the newly proposed method compared with the standard protocol needs to be assessed by measures of agreement. There are different criteria to assess measurement of agreement considering accuracy and precision of the developed model. We calculated coefficient of determination ($R^2$), concordance correlation coefficient, total deviation index, and coverage probability to assess the accuracy and precision of the shortened period compared with regular period. Each of these agreement criteria measures the tendency from different perspectives under normal or log-normal distribution (Rice and Cochran 1984; Block et al. 2010).

Coefficients of determination measure the closeness of fitted data to observed data, and it ranges from 0 to 1, where 1 is a perfect fit. However, $R^2$ cannot determine whether the coefficient estimates and predictions are biased. Concordance correlation coefficients are products of accuracy and precision and are defined as

$$r_c = \frac{2rS_yS_x}{S_y^2 + S_x^2 + (\bar{y} - \bar{x})^2}$$

**Fig. 1.** Variance of different test periods for dry matter intake across and within animal type.




where $r$ is correlation between shortened ($x$) and regular ($y$) DMI, and $S_y, S_x, S_y^2, S_x^2, \bar{y}, \bar{x}$ are standard deviation, variance, and mean, respectively, of shortened ($x$) and regular ($y$) DMI. Concordance correlation coefficient measures agreement from the identity line and its value ranges between −1 and 1; values equal to 1, 0, and −1 mean prefect agreement, no agreement, and perfect disagreement between $x$ and $y$, respectively. When there is evidence of disagreement it is necessary to partition out the sources to find out if this is due to lack of precision (source of within sample variation) or lack of accuracy (marginal distribution). Total deviation index is another measure of tendency which determines the probability of the absolute value of bias (square of residuals) less than the predetermined boundary, $k$, from target values. It is restricted to reasonable relative bias squared values (Lawrence et al. 2002). In this study, $k$ is considered to be equal to variance of DMI and $RFI_{fat}$, in the regular test period. Coverage probability is a statistical criterion which determines percentage of observations within given coverage limitation, and we considered 95% as a coverage limitation.

**Power analysis**

Determining the number of observation to have an acceptable power of test is a crucial step in the planning of a research project. Without adequate power of test, there may be an unacceptable probability of arriving at the conclusion that treatment effects are nil. Type I error ($\alpha$) occurs when a researcher rejects the null hypothesis given that it is true, and the calculated $t$ value falls in the rejection area when the null hypothesis is true. Whereas in type II error ($\beta$), a researcher accepts the null hypothesis given that it is false, and calculated $t$ value does not fall in the rejection area when null hypothesis is false. The probability of type I error rate ($\alpha$) is predetermined by significance level and is typically used for evaluating the test of the null hypothesis. However, type II error rate is a consequence of the experimental design (Park 2008).

Power of test is equal to $1 - \beta$ and defined rejecting the null hypothesis given that it is not true, and the $t$ statistics fall in the rejection area while the hypothesis is false. The value of $\beta$ and power of the test is a function of sample mean ($\mu_a$), standard deviation ($\sigma$), probability ($\alpha$), and sample size ($n$). Power of test is calculated as follows for shortened and regular test period to demonstrate power gain due to increased sample size yielded from shortening the test period in two-tailed test (Park 2008):

$$\text{Power} = P[z < -z_{\alpha/2} - (\mu_a - \mu_o)]\frac{\sqrt{n}}{\sigma} + P[z < z_{\alpha/2} - (\mu_a - \mu_o)]\frac{\sqrt{n}}{\sigma}$$

where $\mu_a - \mu_o$, $\sigma$, $\alpha$, and $n$ are the treatment effect, standard deviation, type I error rate, and sample size, respectively.

## Results and Discussion

**Optimizing DMI measurement period**

Variances for different DMI test periods across and within animal type are presented in Fig. 1. As expected, variances decreased with increasing test days. The relative percentage variance change was steady with increasing test length, and the change was less than 10% after 9, 4, 7, and 9 d on test for feeders, replacement heifers, bulls, and all animals, respectively. Wang et al. (2006) used 446 hybrid steers to test duration for growth, feed intake, and feed efficiency, and they concluded that there was little reduction in variance beyond 35 d in test for DMI. However, the relative percentage variance change could not be considered as a sole source to

**Fig. 2.** Pearson correlation between shortened and regular test periods for dry matter intake within and across animal type.

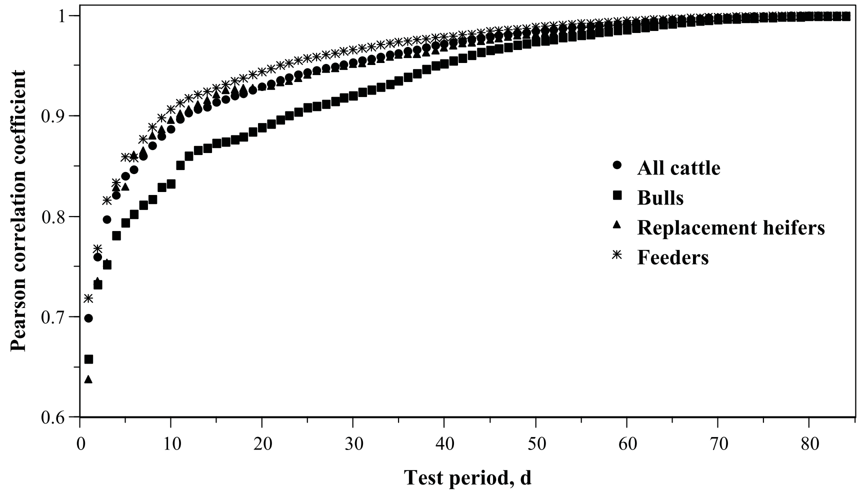
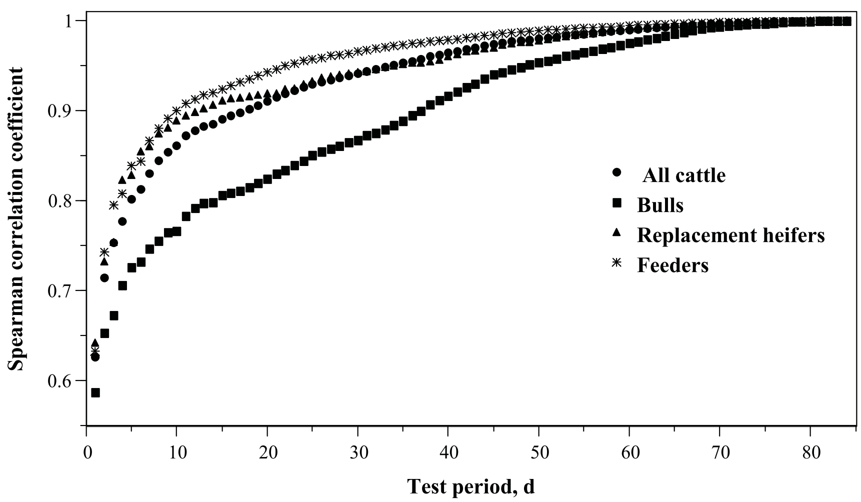



**Fig. 3.** Spearman correlation between shortened and regular test periods for dry matter intake within and across animal type.



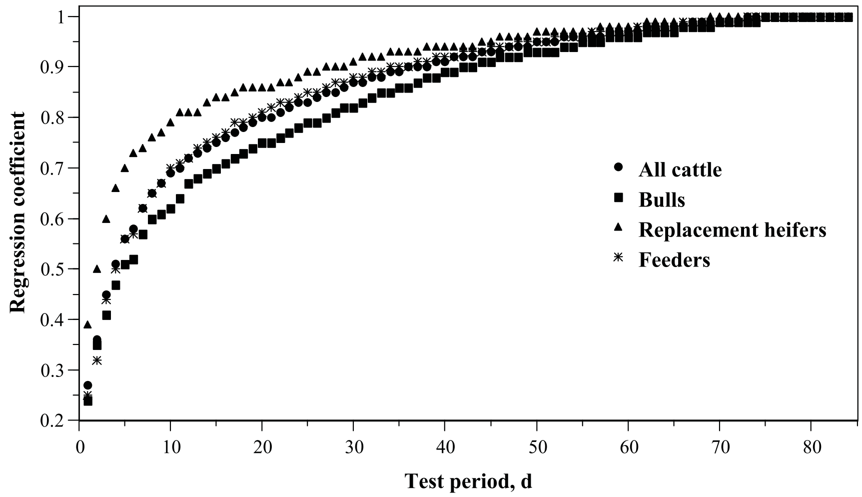



determine optimum test duration (Wang et al. 2006). It is recommended that Pearson and Spearman correlation coefficients, as other factors, could be used to find the optimum test duration, and values closer to unity between shortened and regular test period could represent optimum test period.

Pearson and Spearman correlation coefficients between shortened and regular test periods for DMI are presented in Figs. 2, 3, respectively, and they steadily increased with increasing days on test. Pearson correlation coefficients were 95% beyond 28 d across animal type and 38, 21, and 29 d for bulls, replacement heifers, and feeder animals, respectively. Spearman correlation coefficients of 95% required a few more days for across animal type (34 d), bulls (49 d), replacement heifers (22 d), and feeder animals (34 d). Our results were similar to Culbertson et al. (2015) who reported Pearson and Spearman correlation coefficients of 0.95 for a 28 d test for across animal types including bulls, steers, and heifers. While Wang et al. (2006) reported that Pearson and Spearman correlation coefficients reached 0.95 at 42 d test for steers. In the genetic selection process, animal ranking is more important and gives more weight to the Spearman coefficient. Our results indicate that shortening the DMI measurement period to 34 d across animal type would affect animal ranking by about 5%. However, when bulls are tested a greater duration of test is required.

It has also been recommended to use regression coefficient of regular DMI measurement periods on shortened test to optimize the test length (Kearney et al. 2004; Culbertson et al. 2015). Regression coefficients show the amount of variation in regular test DMI accounted for by shortened test DMI and the amount of bias there

**Fig. 4.** Regression coefficients for regular on shortened test period dry matter intake across and within animal type.




may be in shortened test DMI, expressed as units in regular test period DMI per unit change in shortened test period DMI. Coefficients of regular on shortened period DMI within and across animal type are presented in Fig. 4. With increasing test days, coefficients increased from 0.27 to 1, achieving 0.90 at 36 d on test with $R^2$ equal to 0.97 across animal type. However, a 0.90 coefficient for bulls, replacement heifers, and feeders occurred at 42, 27, and 34 d on test, respectively. Our results were in between values reported by Culbertson et al. (2015) who reported coefficients of 0.89 and 0.99, respectively, at 28 and 42 d on test with $R^2$ of 0.93 and 0.97 across 593 bulls, steers, and heifers. The difference of our results compared with Culbertson et al. (2015) may be due to testing daily reductions in our study compared with biweekly reductions in their study.

In conclusion and based on relative percentage variance change (<2.5%), Pearson and Spearman correlations (>0.97), regression coefficient of 0.92, and $R^2$ of prediction equation equal to 0.98, the regular test period could be decreased to 42 d from 84 d across animal type. Data collection from 42 to 84 d (regular test period) adds 5% in accuracy considering animal type. However, shortening test period for bulls to 42 d could decrease accuracy of bulls ranking by 7% based on Spearman correlation compared with regular period.

#### Reliability of selected shorter DMI on prediction of regular test period DMI and $RFI_{fat}$

In the second objective of this study, we tested reliability of the shortened test period (42 d; valid feed intake days = 30–42 d) to predict regular test (84 d; valid feed intake days = 60–84 d) DMI, and we also test reliability of shortened test period in combination with regular body weight measurement to estimate regular $RFI_{fat}$. Descriptive statistics for shortened (42 d) and regular (84 d) test periods and Pearson correlation coefficient between them for DMI and $RFI_{fat}$ are presented in Table 1. The two test periods had very similar statistics and were highly correlated for DMI ($r$ = 0.97–0.98) and $RFI_{fat}$ ($r$ = 0.87–0.93).

Accuracy and precision criteria of predicted regular DMI from shortened test duration are presented in Table 2. Developed prediction equations were significant ($P > 0.0001$) with a $R^2$ of 0.95, and the regression slope showed that a one unit change in shorter test DMI resulted in a 0.96 unit change in regular test DMI across animal type. A perfectly developed model should generate the same mean and variance. The mean, standard deviation, and range of predicted DMI from shortened period (42 d) were almost identical to recorded DMI for regular period (84 d), and mean bias was negligible (Tables 1 and 2). Predicted DMI from short period and actual DMI in the regular test period were highly correlated ($r$ = 0.96; Table 2). Concordance correlation coefficient value was 0.97, and its value closer to one means prefect agreement between observed and predicted. This agreement was the result of both excellent precision (0.98) and accuracy (0.99), and it means the DMI recorded in shortened test period could accurately and precisely predict DMI in regular period. The excellent performance of the prediction equation was also supported by total deviation $index_{95\%}$ of 1.09 kg $d^{-1}$. This means that 95% of predicted values were within 1.09 kg $d^{-1}$ of their targeted value with upper limit of 1.1, which is much lower than an allowance of 2.26 defined based on SD of regular test period. Coverage probability of 1.00 means 100% of predicted values were in our defined allowance of 2.26. It was concluded that shorter period DMI (42 d; valid feed intake days = 30–42 d) could be used to accurately and precisely predict DMI values measured during a regular test period (84 d; valid feed intake days = 60–84 d). Other researchers concluded that DMI data collection could be shortened to as much as 35 d (Archer et al.

**Table 1.** Descriptive statistics of dry matter intake (DMI) and residual feed intake adjusted for final backfat thickness ($RFI_{fat}$) for shortened (42 d) and regular (84 d) test periods.

| | Animal type | | | |
|---|---|---|---|---|
| | All | Bulls | Replacement heifers | Feeders |
| *N* | 4672 | 1750 | 960 | 1962 |
| **DMI (kg d$^{-1}$)** | | | | |
| Short test period (42 d) | | | | |
| Mean ± SD | 9.30 ± 2.26 | 8.53 ± 1.49 | 7.65 ± 1.24 | 9.00 ± 1.97 |
| Range (min, max) | 14.99 (4.38, 19.37) | 11.47 (4.20, 15.67) | 7.96 (4.19, 12.15) | 12.61 (4.39, 17.00) |
| Regular test period (84 d) | | | | |
| Mean ± SD | 9.66 ± 2.26 | 8.80 ± 1.53 | 7.99 ± 1.18 | 9.35 ± 1.90 |
| Range (min, max) | 15.42 (4.73, 20.15) | 11.24 (4.54, 15.78) | 7.55 (4.70, 12.25) | 12.66 (5.02, 17.69) |
| $R^a$ | 0.98 | 0.97 | 0.97 | 0.98 |
| **$RFI_{fat}$ (kg DM d$^{-1}$)** | | | | |
| Short test period (42 d) | | | | |
| Mean ± SD | 0.00 ± 0.62 | 0.00 ± 0.59 | 0.00 ± 0.49 | 0.00 ± 0.70 |
| Range (min, max) | 5.92 (−2.62, 3.30) | 5.88 (−2.57, 3.30) | 3.52 (−2.09, 1.44) | 5.70 (−2.62, 3.08) |
| Regular test period (84 d) | | | | |
| Mean ± SD | 0.00 ± 0.54 | 0.00 ± 0.51 | 0.00 ± 0.44 | 0.00 ± 0.61 |
| Range (min, max) | 6.00 (−2.60, 3.40) | 5.05 (−2.13, 2.92) | 3.61 (−2.08, 1.53) | 6.0 (−2.61, 3.40) |
| $R^b$ | 0.88 | 0.88 | 0.93 | 0.87 |

[a]Correlation between DMI recorded in shorter and regular test periods.
[b]Correlation between $RFI_{fat}$ recorded in shorter and regular test periods.



**Table 2.** Accuracy and precision criteria of predicted regular dry matter intake (DMI) (84 d) for shortened test period (42 d).

| | Animal type | | | |
|---|---|---|---|---|
| | All | Bulls | Replacement heifers | Feeders |
| *N* | 4672 | 1750 | 960 | 1962 |
| $R^{2a}$ | 0.95 | 0.93 | 0.95 | 0.96 |
| Mean ± SD (kg DM d$^{-1}$)[b] | 9.66 ± 2.22 | 8.88 ± 1.48 | 7.99 ± 1.15 | 9.36 ± 1.87 |
| Range (kg DM d$^{-1}$; min, max)[b] | 14.67 (4.83, 19.50) | 11.34 (4.52, 15.86) | 7.37 (4.78, 12.15) | 11.92 (5.00, 16.93) |
| Intercept ± SE | 0.66 ± 0.03 | 0.36 ± 0.06 | 0.90 ± 0.06 | 0.99 ± 0.04 |
| Slope ± SE | 0.96 ± 0.01 | 0.99 ± 0.01 | 0.93 ± 0.01 | 0.95 ± 0.00 |
| Correlation (%) | 96.5 | 93.0 | 94.60 | 96.10 |
| CCC[c] | 0.97 (0.97) | 0.96 (0.96) | 0.94 (0.94) | 0.97 (0.97) |
| Precision coefficient[d] | 0.98 (0.98) | 0.97 (0.97) | 0.98 (0.97) | 0.98 (0.98) |
| Accuracy coefficient[d] | 0.99 (0.99) | 0.99 (0.99) | 0.97 (0.96) | 0.99 (0.98) |
| Total deviation index (95%) (kg d$^{-1}$)[e] | 1.09 (1.10) | 1.03 (1.05) | 0.87 (0.90) | 1.19 (1.22) |
| Coverage probability (%)[f] | 1.00 (1.00) | 1.00 (1.00) | 1.00 (1.00) | 1.00 (1.00) |
| Relative bias square[g] | 0.69 | 0.42 | 1.28 | 0.83 |
| Allowance[h] | 2.26 | 1.53 | 1.18 | 1.90 |

[a]Coefficient of determination of predication equation of regular DMI from shortened DMI.
[b]Mean and range of predicted DMI for regular test period.
[c]CCC means concordance correlation coefficient, and values in brackets represent upper 95% limit.
[d]Precision and accuracy of CCC, which tests closeness of variation and fit of means, respectively, between shortened and regular test period, and values in parentheses represent upper 95% limit.
[e]A range which 95% of predicted DMI fall in predetermined boundary, which was variance of DMI in regular test period. Values in parentheses represent upper 95% limit.
[f]Percentage of observation within given limitation, which 95% was considered.
[g]A validation indication for calculated total deviation index and coverage probability, which should be >1. The value is greater than 1 for the replacement heifers, which means it is not reliable for this type of animal.
[h]A defined arbitrary value for total deviation index and coverage probability calculation, which was equal to standard deviation of recorded DMI in regular period.

**Table 3.** Accuracy and precision criteria of predicted regular residual feed intake adjusted for final backfat thickness ($RFI_{fat}$) (84 d) for shortened test period (42 d).

| | Animal type | | | |
|---|---|---|---|---|
| | All | Bulls | Replacement heifers | Feeders |
| *N* | 4672 | 1750 | 960 | 1962 |
| $R^{2a}$ | 0.78 | 0.77 | 0.86 | 0.75 |
| Mean ± SD (kg DM $d^{-1}$)[b] | 0.00 ± 0.48 | 0.00 ± 0.45 | 0.00 ± 0.41 | 0.00 ± 0.54 |
| Range (kg DM $d^{-1}$; min, max)[c] | 4.59 (−2.03, 2.56) | 4.50 (−1.97, 2.92) | 2.96 (−1.76, 1.21) | 4.37 (−2.01, 2.36) |
| Intercept ± SE | 0.00 ± 0.01 | 0.00 ± 0.01 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Slope ± SE | 0.78 ± 0.01 | 0.77 ± 0.01 | 0.82 ± 0.01 | 0.75 ± 0.01 |
| Slope (%) | 22.00 | 22.83 | 14.36 | 22.25 |
| Correlation (%) | 78.00 | 77.22 | 84.74 | 77.80 |
| CCC[d] | 0.88 (0.87) | 0.87 (0.86) | 0.92 (0.920) | 0.87 (0.86) |
| Precision coefficient[d] | 0.88 (0.88) | 0.88 (0.87) | 0.93 (0.92) | 0.88 (0.87) |
| Accuracy coefficient[d] | 0.99 (0.99) | 0.99 (0.99) | 1.00 (1.00) | 1.00 (0.99) |
| Total deviation index (95%) (kg $d^{-1}$)[e] | 0.57 (0.58) | 0.55 (0.56) | 0.36 (0.37) | 0.65 (0.66) |
| Coverage probability (%)[f] | 0.93 (0.93) | 0.93 (0.92) | 0.98 (0.98) | 0.94 (0.93) |
| Relative bias square[g] | 0.00 | 0.00 | 0.00 | 0.00 |
| Allowance (kg DM $d^{-1}$)[h] | 0.54 | 0.51 | 0.44 | 0.61 |

[a]Coefficient of determination of predication equation of regular dry matter intake (DMI) from shortened DMI.
[b]Mean and range of predicted DMI for regular test period.
[c]CCC means concordance correlation coefficient, and values in parentheses represent upper 95% limit.
[d]Precision and accuracy of CCC, which tests closeness of variation and fit of means, respectively, between shortened and regular test period, and values in parentheses represent upper 95% limit.
[e]A range which 95% of predicted $RFI_{fat}$ fall in predetermined boundary, which was variance of $RFI_{fat}$ in regular test period. Values in parentheses represent upper 95% limit.
[f]Percentage of observation within given limitation, which 95% was considered.
[g]A validation indication for calculated total deviation index and coverage probability, which should be >1.
[h]A defined arbitrary value for total deviation index and coverage probability calculation, which was equal to standard deviation of recorded $RFI_{fat}$ in regular period.



1997; Wang et al. 2006) and 42 d (Culbertson et al. 2015) using different statistical criteria.

Accuracy and precision of predicted $RFI_{fat}$ from shortened test duration are presented in Table 3. It is noteworthy that shorter $RFI_{fat}$ was estimated using shorter DMI and regular BW measurement while regular $RFI_{fat}$ was estimated using regular DMI records and BW measurements. Developed prediction equations were significant ($P > 0.0001$) with $R^2$ equal to 0.78, and mean bias for $RFI_{fat}$ equal to zero as expected by the nature of its calculation. However, the slope value for $RFI_{fat}$ was 0.78, which caused lower standard deviation and range of predicted $RFI_{fat}$ compared with estimated $RFI_{fat}$ from recorded 60–84 d DMI (Tables 1 and 3). However, an animal's rank is more important than their $RFI_{fat}$ values. The $RFI_{fat}$ values estimated from short and regular test period were moderately to highly correlated ($r = 0.78$), and had a high concordance correlation coefficient (0.88). This agreement was the result of both adequate precision (0.88) and excellent accuracy (0.99). In traits such as $RFI_{fat}$ which have an expected mean of zero, the weight of model precision is more important than the accuracy. Measuring DMI over a shorter period of time will result in a loss of precision by 12%. The total deviation $index_{95\%}$ of $RFI_{fat}$ was 0.57 kg $d^{-1}$. It means 95% of predicted values were within 0.57 kg DM $d^{-1}$ of their targeted value with upper limit of 0.58, which is slightly higher than the arbitrary value of 0.54. Coverage probability of 0.93 indicating 93% of predicted values was in our defined allowance of 0.54, the standard deviation of regular test $RFI_{fat}$. In other words, we could expect to have 7% of values predicted outside of regular test period values. Wang et al. (2006) suggested that 63 d for a RFI test based on Pearson and Spearman correlation coefficient of 0.9 and relative variance change of 7%. Culbertson et al. (2015) recently suggested a shorter RFI test period of 56 d considering regression coefficient of 1 with $R^2$ of prediction equation of 0.89, and Pearson correlation of 0.94 and Spearman correlation of 0.95. Our results were different from previous results, and it could be due to using regular BW measurements and having different animal types in the dataset. It was concluded that $RFI_{fat}$ estimation period could successfully be decreased by reducing DMI test period to 42 d with a minimum of 30 valid feed intake days, if BW measurements are recorded as usual for the regular test period (84 d). However, it will result in 7% of predicted values outside the predicted range and a loss of 12% of the precision.

**Power of the test**

Shortening the DMI test period (from 84 to 42 d) could potentially double the number of animals to be tested using the same facilities, and we demonstrated the effect of doubling sample size on the power of test considering changes in mean and standard deviation due to changing the test period. We also considered the hypothetical treatment effect to be detected as significant ($\alpha = 0.05$) would be 1 kg. Using mean and standard deviation of regular test and shortened test period across animal type (Table 1), we calculated power of test for the regular test period with $n = 20$ and for shortened test period with $n = 40$. The results showed that power of test in the case of shorter test period is increased to 0.80 from 0.51 for the regular test period. This means that there is a 29% greater chance of correctly accepting the null hypothesis when it is in fact true using the shorter test period and a greater number of animals.

For the $RFI_{fat}$ measure of efficiency, the SD was increased slightly (from 0.52 to 0.62) when the measure of intake were from different periods. This inflation in the SD of $RFI_{fat}$ was offset by the change in number of animals. Thus, the gain in power due to doubling sample size was approximately 28% (from 0.54 with $n = 20$ in regular test period to 0.72 with $n = 40$ in shortened test period) for $RFI_{fat}$ test. The mean and standard deviation values were used from Table 1 and the amount of 0.25 was set as the minimum difference of mean between null and alternative hypothesis (treatment effect at $\alpha = 0.05$) for power calculation.

## Conclusion

Results of this study suggest that the regular period of DMI data collection could be decreased from 84 to 42 d across animal type. Additional feed intake measurements beyond 42 d potentially add 5% in accuracy. Reducing the feed intake measurement period would allow feed intake measurements for increased numbers of animals as long as BW is measured for an adequate duration outside of the feed measurement period. It was also concluded that $RFI_{fat}$ estimation period could successfully be decreased with a reduced DMI recording period of 42 d with a minimum of 30 d of valid feed intake days, and having BW measurement as usual in the regular test period. Implementing this strategy will allow for more powerful experiments testing hypotheses regarding feed efficiency.

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