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Test duration for water intake, ADG, and DMI in beef cattle[1]

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ABSTRACT: Water is an essential nutrient, but the effect it has on performance generally receives little attention. There are few systems and guidelines for collection of water intake (**WI**) phenotypes in beef cattle, which makes large-scale research on WI a challenge. The Beef Improvement Federation has established guidelines for feed intake (**FI**) and ADG tests, but no guidelines exist for WI. The goal of this study was to determine the test duration necessary for collection of accurate WI phenotypes. To facilitate this goal, individual daily WI and FI records were collected on 578 crossbred steers for a total of 70 d using an Insentec system at the Oklahoma State University Willard Sparks Beef Research Unit. Steers were fed in five groups and were individually weighed every 14 d. Within each group, steers were blocked by BW (low and high) and randomly assigned to one of four pens containing approximately 30 steers per pen. Each pen provided 103.0 m^2 of shade and included an Insentec system containing six feed bunks and one water bunk. Steers were fed a constant diet across groups and DMI was calculated using the average of weekly percent DM within group. Average FI and WI for each animal were computed for increasingly large test durations (7, 14, 21, 28, 35, 42, 49, 56, 63, and 70 d), and ADG was calculated using a regression formed from BW taken every 14 d (0, 14, 28, 42, 56, and 70 d). Intervals for all traits were computed starting from both the beginning (day 0) and the end of the testing period (day 70). Pearson and Spearman correlations were computed for phenotypes from each shortened test period and for the full 70-d test. Minimum test duration was determined when the Pearson correlations were greater than 0.95 for each trait. Our results indicated that minimum test duration for WI, DMI, and ADG were 35, 42, and 70 d, respectively. No comparable studies exist for WI; however, our results for FI and ADG are consistent with those in the literature. Although further testing in other populations of cattle and areas of the country should take place, our results suggest that WI phenotypes can be collected concurrently with DMI, without extending test duration, even if following procedures for decoupled intake and gain tests.

Key words: beef cattle, feed intake, Insentec, test duration, water intake

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INTRODUCTION

Water is an essential nutrient that contributes to livestock production and health (Thornton et al., 2009), but measurement of water intake (**WI**) on individual animals has received fairly little attention in the recent scientific literature. Growing competition between human consumption, crop production, wildlife, and livestock has led to concerns about the availability of water in some regions of the world (World Economic Forum, 2017). Additionally, consumer concerns related to beef sustainability and environmental resource usage have increased in recent years (Nardone et al., 2010). These issues necessitate a systematic and accurate method for the collection of WI phenotypes in beef cattle to determine heritability as well as the impact of WI on beef production.

Accurate phenotypic data are essential for any genetic study. Obtaining accurate data for DMI and WI on individual animals requires collection of daily performance measures over a period of time. The Beef Improvement Federation (BIF, 2016) guidelines recommend a 70-d minimum test duration for ADG and a 45-d minimum test duration for feed intake (**FI**). For ADG, research by Franklin et al. (1987) suggests 112 d, Lui and Makarechian (1993) suggests 84 d, Archer et al. (1997) and Wang et al. (2006) suggest that a 63- to 70-d test duration is adequate. Recommendations for DMI are shorter at around 35 d (Archer et al., 1997; Wang et al., 2006; Culbertson et al., 2015; Cassady et al., 2016; Retallick et al., 2017). Decoupling the collection of FI and ADG has been proposed by Retallick et al. (2017), which suggests the use of postweaning ADG as a substitute for gain and collection of FI separately. This would allow a shortened test duration. Although the importance of standardized tests for production traits such as ADG and DMI has previously been established, there are no established guidelines for collection of WI phenotypes in beef cattle. The objective of this study was to determine the required test duration to accurately collect WI phenotypes.

MATERIALS AND METHODS

Study Design

Water intake and FI were collected using an Insentec system at the Willard Sparks Beef Research Center located at Oklahoma State University in Stillwater, OK. This Insentec system consisted of one water bunk and six feed bunks per pen. The facility contained four pens, with each pen providing 11.27 by 31.85 m (358.95 m^2) of space, 103.0 m^2 of which was covered. The Roughage Intake Control (**RIC**) management software utilized by the system calculates WI and FI by subtracting the starting and ending weights of the bunks while simultaneously collecting additional data, such as the duration of each visit. Additional information on system specifications, accuracy, and specificity of the Insentec system can be found in Allwardt et al. (2017) and Chapinal et al. (2007).

Daily WI and as-fed FI were collected on 578 crossbreed steers over a 3-yr period. All animal procedures were approved by the Institutional Animal Care and Use Committee at Oklahoma State University (protocol AG13-18) in accordance with Federation of Animal Science Societies (FASS, 2010) guidelines. Steers were fed in five different groups across different seasons: group 1 (n = 117) from May 2014 to August 2014, group 2 (n = 116) from November 2014 to January 2015, group 3 (n = 118) from May 2015 to July 2015, group 4 (n = 105) from June 2016 to August 2016, and group 5 (n = 123) from January 2017 to March 2017. Within each group, steers were blocked by BW (low and high) and randomly assigned to one of four pens, each containing approximately 30 steers per pen.

Before entry into the test facility, each animal received a plastic tag for identification and a passive half-duplex radio frequency eID (Allflex USA Inc., Dallas-Fort Worth, TX) placed in the left ear. All groups were fed a growing diet throughout the study that consisted of 15% cracked corn, 51.36% wet corn gluten feed Sweet Bran (Cargill Corn Milling, Dalhart, Texas), 28.44% prairie hay, and 5.20% supplement on a DM basis. Diet samples were taken weekly for DM collection, and a portion of each sample collected was composited and analyzed for nutrient content. The average percent DM was 74.02%, 73.70%, 73.11%, 73.24%, and 70.04% for groups 1, 2, 3, 4, and 5, respectively, which was used to convert FI to DMI. The mean GE of composited samples was 4,524.6 cal/g on a DM basis. Steers fed in groups 1–3 were managed using a slick bunk feed call procedure (slick), and steers fed during groups 4 and 5 had access to ad libitum (**adlib**) FI. Regardless of the feed management protocol, all steers had adlib access to water. Intakes were collected over a 70-d period following a 21-d acclimation period to be in accordance with standard test duration guidelines for FI and BW gain published by the Beef Improvement Federation (BIF, 2016). Individual BW was collected at the beginning and end of the testing periods, and every 14 d during the test. Body weights were not recorded on day 42 for group 2 because of equipment malfunction. The Insentec system has been validated for both accuracy of FI and WI collection (Chapinal et al., 2007; Allwardt et al., 2017) and restriction of WI (Allwardt et al., 2017).

To ensure data quality, FI and WI records were filtered for bunk starting weight, ending weight, and duration of time in the system. Start and end weight parameters were set to filter out records with unreasonable starting and ending weights, such as large negative values or weights that were significantly larger than the bunk capacity. Intake visits that were less than 5 s were removed. Water intake data collected on days where adlib WI was not achieved, such as weigh dates or incidences of equipment malfunction, were treated as missing to maintain data quality. In groups 1–3, daily FI were treated as missing on days where animals were removed from their pens (such as weigh dates) or for equipment malfunctions. Feed intakes were also treated as missing on days that adlib intake was not achieved for groups 4 and 5.

Phenotypic Data

Individual daily FI was converted to daily DMI using the following equation

$$\mathrm{DMI}_{di} = \mathrm{FI}_{di} \times \mathrm{DM\%}_g$$

where DMI_{di} is the DMI for animal i on day d, FI_{di} is the FI for animal i on day d, and $\mathrm{DM\%}_g$ is the mean DM percentage for the ration fed to group g expressed as a decimal.

Because BW will be affected by rumen fill and other environmental factors, a linear regression of individual-observed BW against days on test was used to calculate ADG to better account for these differences. The regression was as follows:

$$\mathrm{BW}_{id} = b_0 + \mathrm{ADG}_i\, x_d + e_{id}$$

where BW_{id} is the observed BW of animal i measured on day d of the test period, b_0 is the estimate of the initial BW of each animal at the start of the test period, ADG_i is the estimated ADG for animal i, x_d is the test day d of the study, and e_{id} is the residual error. Summary statistics for phenotypic data (ADG, DMI, and WI) are presented in Table 1.

Average WI and DMI for each animal were computed for increasingly longer test periods in 7-d increments starting on day 1 and increasing until the full data set (forward) was utilized (F7, F14, F21, F28, F35, F42, F49, F56, F63, and F70 d). Feed and WI were also calculated starting from the end of the test period (day 70, reverse) using the same approach (R7, R14, R21, R28, R35, R42, R49, R56, R63, and R70 d). Each individual animal had to have a minimum of 3 d of intake records within each window to be considered for analysis. Similarly, ADG for each animal was also computed for increasingly longer test periods in 14-d intervals to correspond with the BW data available in both the forward (F14, F28, F42, F56, and F70 d) and reverse direction (R14, R28, R42, R58, and R70 d). Means and SD for WI, DMI, and ADG were estimated for each shortened test period within each group, management type, and across all data using the MEANS procedure of SAS 9.4 (SAS Institute Inc., Cary, NC). Phenotypic (Pearson and Spearman) correlations were also estimated for each shortened test duration compared to the full 70-d test period and the Fisher option within the CORR procedure of SAS 9.4 (SAS Institute Inc.) was used to test whether correlations were significantly different from 0.95. Previous work by Archer et al. (1997) and Wang et al. (2006) set a less stringent level of 0.90 for Spearman correlations to determine if a shortened test duration for DMI and ADG were acceptable. In this study, minimum recommended test duration for WI was determined when Pearson correlations were greater than 0.95, in accordance with the level used for the BIF guidelines (BIF, 2016). Spearman correlations were utilized to determine the amount of re-ranking, or differences in order from highest to lowest intakes, between individuals when test length differed.

Table 1. Summary statistics for ADG, average daily DMI, and average daily water intake (WI) over the 70-d test period

Trait	Mean	SD[1]	Min	Max	CV%[1]
ADG, kg	1.55	0.37	0.41	2.55	24.0
DMI, kg	10.54	1.51	5.80	16.25	14.3
WI, kg	37.69	11.28	14.02	108.32	29.9

[1]CV% is CV reported as a percent.

RESULTS AND DISCUSSION

ADG Test Duration

Means and their corresponding SD for each subset analyzed are shown in Table 2, and illustration of means for all animals is presented Fig. 1A. Little variation was observed in ADG as test

Table 2. Means (SD) for a 70-d ADG (kg) test[1]

Group	Direction[2]	Test duration 14	28	42	56	70
1	Forward	1.33 (0.85)	1.46 (0.61)	1.31 (0.43)	1.46 (0.35)	1.39 (0.29)
	Reverse	0.69 (0.78)	1.44 (0.43)	1.36 (0.31)	1.39 (0.28)	1.39 (0.29)
2	Forward	1.87 (0.87)	1.78 (0.62)	1.78 (0.62)	1.79 (0.37)	1.74 (0.34)
	Reverse	1.42 (0.72)	1.42 (0.72)	1.70 (0.43)	1.71 (0.36)	1.74 (0.34)
3	Forward	1.16 (1.17)	1.74 (0.66)	1.65 (0.46)	1.55 (0.38)	1.46 (0.31)
	Reverse	1.11 (1.35)	1.18 (0.58)	1.19 (0.39)	1.43 (0.33)	1.46 (0.31)
4	Forward	1.13 (0.61)	1.50 (0.44)	1.53 (0.37)	1.39 (0.31)	1.27 (0.29)
	Reverse	0.83 (0.75)	0.81 (0.46)	1.01 (0.46)	1.21 (0.29)	1.27 (0.29)
5	Forward	2.73 (0.91)	2.16 (0.47)	1.96 (0.34)	1.85 (0.29)	1.83 (0.29)
	Reverse	2.12 (0.84)	1.75 (0.49)	1.66 (0.37)	1.60 (0.33)	1.83 (0.29)
All	Forward	1.67 (1.09)	1.74 (0.62)	1.65 (0.51)	1.61 (0.39)	1.54 (0.37)
	Reverse	1.25 (1.05)	1.34 (0.63)	1.40 (0.45)	1.48 (0.36)	1.54 (0.37)

[1]Shorter test durations are subsets of the full 70-d test of the specified duration. Forward analyses begin at day 0 and reverse analyses begin at day 70.

[2]Forward-records were split into the first F14, F28, F42, F56, and F70 d of the test, reverse-records were split into the last R14, R28, R42, R56, and R70 d of the test.

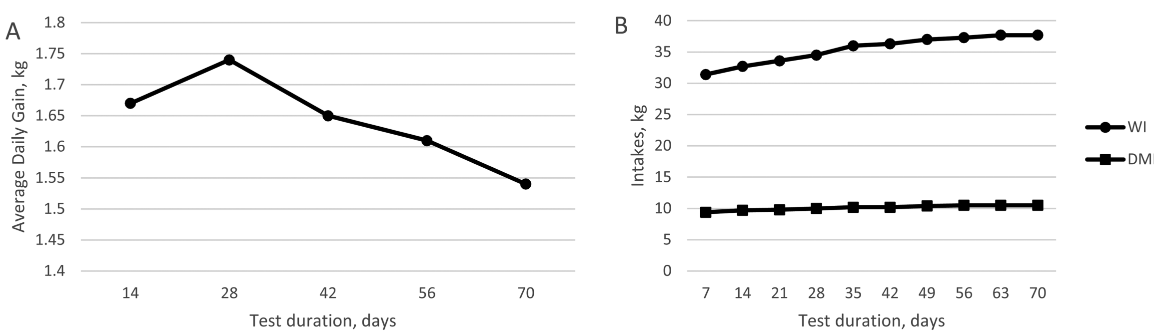

Figure 1. (A) Mean ADG for all animals throughout the 70-d test, (B) mean average daily water intake (WI) and average daily DMI throughout the 70-d test.

duration increases. For all groups, as test duration increases, variation decreases for ADG. However, the means for ADG vary within group. Mean ADG for groups 2 and 5 were observed to have decreasing BW gain as test duration increased. When examining groups 3 and 4, ADG increased through the middle of the testing period and then decreased throughout the remainder of the test. Group 1 exhibited variation in ADG throughout the test period. Differences in mean ADG between groups could be at least partially attributed to differences in temperature observed for each group. Growth is only maximized during a narrow thermal neutral range. When environmental conditions are not ideal, energy and nutrients are diverted away to maintain euthermia, which can decrease performance (O'Brien et al., 2010). The cooler temperatures during the latter part of the feeding period for groups 3 could have required the animals to put more energy toward maintenance and less toward gain. Birkelo et al. (1991) and Mader (2003) showed a decrease in ADG for finished cattle fed during the winter as compared to those fed during the summer. Ames and Ray (1983) explained that during times of cold stress, maintenance energy requirements increase linearly as temperature decreases. Rate of feed consumption increases in cattle as temperature decreases, but this usually does not compensate for the increase in maintenance energy requirements (Ames and Ray, 1983). Increases in maintenance energy requirements during heat stress (THI > 74; Mader et al., 2006) are attributed to increased energy expenditure for heat loss through panting and sweating (Wheelock et al., 2010), which could potentially result in lower ADG. During times when heat load increases, cattle decrease FI to lessen heat production, which may also affect ADG during those times (Ames and Ray, 1983).

Pearson and Spearman correlations for subsets of the 70-d test period are shown for individual groups, feed management groups, and for data combined across groups in Table 3 and confidence intervals are presented in Supplementary Table S1. Graphical representations of these correlations are

Table 3. Pearson and Spearman correlations for each shortened test duration and the full 70-d test period for ADG (kg)

			Test duration (d)				
Group[1]	Direction[2]	Analysis	14	28	42	56	70
1	Forward	Pearson	0.465	0.711	0.822	0.885	1.0
		Spearman	0.396	0.726	0.781	0.929	1.0
	Reverse	Pearson	0.123	0.495	0.635	0.892	1.0
		Spearman	0.262	0.509	0.632	0.895	1.0
2	Forward	Pearson	0.375	0.601	0.601	0.943	1.0
		Spearman	0.360	0.562	0.562	0.934	1.0
	Reverse	Pearson	0.393	0.393	0.730	0.929	1.0
		Spearman	0.430	0.430	0.748	0.909	1.0
3	Forward	Pearson	0.303	0.566	0.760	0.885	1.0
		Spearman	0.266	0.527	0.731	0.876	1.0
	Reverse	Pearson	0.118	0.404	0.636	0.880	1.0
		Spearman	0.190	0.371	0.599	0.849	1.0
4	Forward	Pearson	0.600	0.707	0.834	0.932	1.0
		Spearman	0.541	0.661	0.819	0.927	1.0
	Reverse	Pearson	0.424	0.583	0.827	0.953	1.0
		Spearman	0.418	0.552	0.815	0.957	1.0
5	Forward	Pearson	0.296	0.574	0.857	0.913	1.0
		Spearman	0.290	0.559	0.831	0.910	1.0
	Reverse	Pearson	0.515	0.657	0.827	0.937	1.0
		Spearman	0.472	0.602	0.804	0.930	1.0
Slick	Forward	Pearson	0.431	0.617	0.720	0.930	1.0
		Spearman	0.419	0.623	0.722	0.924	1.0
	Reverse	Pearson	0.276	0.389	0.713	0.919	1.0
		Spearman	0.384	0.389	0.798	0.912	1.0
Adlib	Forward	Pearson	0.700	0.775	0.879	0.949	1.0
		Spearman	0.736	0.770	0.860	0.940	1.0
	Reverse	Pearson	0.702	0.808	0.907	0.940	1.0
		Spearman	0.732	0.812	0.913	0.934	1.0
All	Forward	Pearson	0.549	0.673	0.759	0.934	1.0
		Spearman	0.563	0.684	0.768	0.935	1.0
	Reverse	Pearson	0.458	0.579	0.795	0.912	1.0
		Spearman	0.531	0.578	0.798	0.905	1.0

[1]Slick-cattle managed with slick bunk feed protocol, adlib-cattle had access to ad libitum feed, all–all groups were combined.

[2]Forward-records were split into the first F14, F28, F42, F56, and F70 d of the test and reverse-records were split into the last R14, R28, R42, R56, and R70 d of the test.

presented in Supplementary Fig. S1. As expected, as test duration increases, Spearman and Pearson correlations also increase, regardless of whether the calculations are made starting at the beginning of the test (F14–F70) or from the end (R14–R70). Within group, there are differences in the degree of increase in correlation as test duration increases. The majority of the groups showed large increases in their correlations with the addition of another data point when the number of days on test was low. Although some of the confidence intervals (Supplementary Table S1) do overlap 0.95 at 56 d within individual groups, these data indicate that the test duration for collection of ADG is likely a minimum of 70 d, which is generally consistent with estimates in the literature and the BIF guidelines (BIF, 2016). Slight differences were observed in Pearson and Spearman correlations for the slick bunk and adlib feeding groups, with both Pearson and Spearman correlations being lower at the earliest time points for the slick bunk groups. Despite these differences, data from both management types and the data combined across groups suggest a 70-d feeding period is necessary to measure ADG.

Recommendations for ADG test duration in the literature are 112 d (Franklin et al., 1987), 84 d (Lui and Makarechian, 1993), 70 d (Archer et al., 1997), and 63 d (Wang et al., 2006). The data from Wang et al. (2006) may have supported a shorter test duration because they used more frequent (weekly) BW measurements instead of every 14 d (the present study and Archer, 1997) or every 28 d

(Franklin et al., 1987; Lui and Makarechian, 1993). We did not have a test period longer than 70 d for comparison because the experiment was designed to follow the BIF guidelines for ADG and DMI test duration. Thus, even though the Pearson and Spearman correlations are approaching our threshold of 0.95 (especially in the forward analysis) at 56 d, it is impossible to say definitively whether our correlations would have surpassed 0.95 on day 70 if we had employed a longer testing period.

DMI Test Duration

Means and their corresponding SD for subsets and the full 70-d test period are shown in Table 4 and illustration of mean DMI for all animals is presented in Fig. 1B. As expected, when test duration increased (F7–F70), DMI increased and the variation decreased for all the groups except for group 4. In contrast, DMI for group 4 decreased as the test duration increased. Hahn (1999) showed that as temperature continuously exceeds 25 °C, cattle exhibit a decrease in feed consumption. Cattle experiencing heat stress have reduced intake and a nonlinear increase in maintenance energy requirements, which can lead to reduced performance (Ames and Ray, 1983). Temperatures in group 4 exceeded 25 °C for 61 d out of the 70-d test. Even though intakes decreased for group 4, the SD decreased as test duration increased, similar to the other groups. When test duration is evaluated starting at the end of the test period (R7–R70), DMI tends to increase slightly and then have a slight decline for the rest of the test period for most of the groups. When data are combined across groups and analyzed starting at the end of the test, DMI increases slightly from days 7 to 35 and then there is a slight decrease in DMI from days 35 to 70.

Pearson and Spearman correlations for subsets of the 70-d test period are shown in Table 5, illustrated graphically in Supplementary Fig. S2, and confidence intervals are provided in Supplementary Table S2. Based on the Pearson correlations, minimum test duration for DMI would be 42 d. However, if the last 42 d of the test period are considered rather than the first, the correlations consistently do not meet the 0.95 threshold (0.949) until 49 d of data are included. Within most groups, the confidence intervals overlap 0.95 for both forward and reverse analyses when at least 42 d of data are utilized. If re-ranking of individuals is important, then the Spearman correlations may be the preferred metric. In this analysis of DMI, correlations were similar for both forward and reverse analyses. For the slick bunk managed cattle, the Pearson correlation exceed the 0.95 threshold at day 42 in the forward direction and day 49 in the reverse direction, which was identical to the result derived from using all of the data combined. However, the Pearson correlation was not significantly different from 0.95 at day 35 in the forward direction. The adlib fed cattle met the Pearson correlation threshold of 0.95 at F42 and R35, similar to results presented by Cassady et al. (2016). Wang et al. (2006) reported Pearson (0.929) and Spearman (0.931) correlations for DMI over 35 d using a GrowSafe system, which were slightly lower than in the present study. Pearson and Spearman correlations for

Table 4. Means (SD) for a 70-d daily DMI (kg) test[1]

		Day of test									
Group	Direction[2]	7	14	21	28	35	42	49	56	63	70
1	Forward	7.8 (2.4)	8.5 (2.2)	9.1 (2.0)	9.5 (1.9)	9.6 (1.7)	9.7 (1.6)	9.8 (1.6)	9.9 (1.5)	10.0 (1.5)	10.1 (1.4)
	Reverse	10.4 (1.4)	10.6 (1.3)	10.7 (1.3)	10.6 (1.3)	10.6 (1.3)	10.5 (1.3)	10.5 (1.4)	10.5 (1.4)	10.3 (1.4)	10.1 (1.4)
2	Forward	8.2 (2.1)	8.6 (2.0)	8.9 (2.0)	9.2 (1.9)	9.5 (1.8)	9.7 (1.8)	10.0 (1.8)	10.2 (1.7)	10.2 (1.7)	10.2 (1.7)
	Reverse	10.9 (1.8)	10.4 (1.8)	10.8 (1.7)	10.9 (1.7)	11.0 (1.7)	10.9 (1.7)	10.8 (1.7)	10.6 (1.7)	10.4 (1.7)	10.2 (1.7)
3	Forward	9.5 (2.2)	9.5 (2.1)	9.7 (2.0)	9.8 (2.0)	9.9 (1.7)	9.7 (1.7)	9.8 (1.7)	10.0 (1.6)	10.0 (1.5)	10.0 (1.5)
	Reverse	10.4 (1.4)	10.4 (1.3)	10.5 (1.3)	10.6 (1.4)	10.2 (1.3)	10.2 (1.4)	10.2 (1.4)	10.2 (1.4)	10.1 (1.5)	10.0 (1.5)
4	Forward	11.2 (1.3)	11.1 (1.2)	10.6 (1.0)	10.7 (1.1)	10.6 (1.0)	10.7 (1.0)	10.8 (1.0)	10.7 (1.0)	10.7 (0.9)	10.6 (0.9)
	Reverse	9.8 (1.0)	10.1 (1.0)	10.2 (0.9)	10.4 (1.0)	10.6 (1.0)	10.6 (1.0)	10.6 (0.9)	10.5 (0.9)	10.5 (0.9)	10.6 (0.9)
5	Forward	10.6 (1.4)	10.7 (1.3)	10.9 (1.2)	11.0 (1.2)	11.2 (1.2)	11.3 (1.2)	11.5 (1.2)	11.6 (1.2)	11.7 (1.2)	11.7 (1.2)
	Reverse	11.9 (1.6)	12.0 (1.5)	12.2 (1.4)	12.3 (1.4)	12.2 (1.4)	12.1 (1.3)	12.0 (1.3)	11.9 (1.3)	11.8 (1.3)	11.7 (1.2)
All	Forward	9.4 (2.3)	9.7 (2.1)	9.8 (1.9)	10.0 (1.8)	10.2 (1.7)	10.2 (1.6)	10.4 (1.6)	10.5 (1.6)	10.5 (1.5)	10.5 (1.5)
	Reverse	10.7 (1.6)	10.8 (1.6)	10.9 (1.5)	11.0 (1.5)	10.9 (1.5)	10.9 (1.5)	10.8 (1.5)	10.7 (1.5)	10.6 (1.5)	10.5 (1.5)

[1]Shorter test durations are subsets of the full 70-d test of the specified duration. Forward analyses begin at day 0 and reverse analyses begin at day 70.

[2]Forward-records were split into the first F7, F14, F21, F28, F35, F42, F49, F56, F63, and F70 d of the test and reverse-records were split into the last R7, R14, R21, R28, R35, R42, R49, R56, R63, and R70 d of the test.

Table 5. Pearson and Spearman correlations for each shortened test duration and the full 70-d test period for DMI (kg)

			Day of test									
Group[1]	Direction[2]	Analysis	7	14	21	28	35	42	49	56	63	70
1	Forward	Pearson	0.709	0.777	0.855	0.902	0.941	0.963	0.983	0.991	0.997	1.0
		Spearman	0.747	0.809	0.866	0.903	0.940	0.959	0.979	0.988	0.997	1.0
	Reverse	Pearson	0.699	0.781	0.852	0.868	0.893	0.914	0.947	0.968	0.992	1.0
		Spearman	0.734	0.793	0.856	0.879	0.905	0.918	0.947	0.966	0.990	1.0
2	Forward	Pearson	0.782	0.828	0.883	0.921	0.951	0.967	0.983	0.990	0.998	1.0
		Spearman	0.812	0.848	0.899	0.922	0.953	0.966	0.981	0.989	0.997	1.0
	Reverse	Pearson	0.821	0.840	0.891	0.913	0.937	0.953	0.972	0.985	0.997	1.0
		Spearman	0.839	0.840	0.886	0.902	0.928	0.945	0.972	0.986	0.996	1.0
3	Forward	Pearson	0.832	0.892	0.916	0.935	0.958	0.975	0.986	0.993	0.998	1.0
		Spearman	0.815	0.894	0.915	0.924	0.950	0.969	0.984	0.992	0.998	1.0
	Reverse	Pearson	0.805	0.813	0.869	0.906	0.915	0.938	0.968	0.986	0.996	1.0
		Spearman	0.812	0.825	0.877	0.909	0.917	0.938	0.966	0.982	0.994	1.0
4	Forward	Pearson	0.797	0.868	0.899	0.929	0.955	0.969	0.985	0.992	0.998	1.0
		Spearman	0.747	0.842	0.885	0.924	0.952	0.965	0.984	0.992	0.997	1.0
	Reverse	Pearson	0.810	0.872	0.899	0.927	0.955	0.961	0.977	0.987	0.996	1.0
		Spearman	0.841	0.894	0.919	0.940	0.961	0.967	0.976	0.987	0.994	1.0
5	Forward	Pearson	0.770	0.840	0.881	0.908	0.942	0.966	0.981	0.988	0.997	1.0
		Spearman	0.734	0.826	0.856	0.890	0.927	0.951	0.972	0.982	0.995	1.0
	Reverse	Pearson	0.786	0.867	0.923	0.945	0.955	0.966	0.982	0.991	0.997	1.0
		Spearman	0.793	0.889	0.922	0.941	0.955	0.960	0.976	0.988	0.996	1.0
Slick	Forward	Pearson	0.721	0.803	0.863	0.905	0.941	0.967	0.983	0.991	0.998	1.0
		Spearman	0.736	0.813	0.865	0.901	0.938	0.966	0.982	0.990	0.997	1.0
	Reverse	Pearson	0.776	0.809	0.872	0.896	0.905	0.928	0.957	0.977	0.994	1.0
		Spearman	0.794	0.818	0.876	0.897	0.907	0.929	0.958	0.976	0.993	1.0
Adlib	Forward	Pearson	0.584	0.664	0.831	0.886	0.931	0.952	0.975	0.988	0.997	1.0
		Spearman	0.536	0.622	0.797	0.860	0.916	0.938	0.964	0.982	0.995	1.0
	Reverse	Pearson	0.832	0.890	0.919	0.940	0.956	0.966	0.979	0.985	0.996	1.0
		Spearman	0.835	0.892	0908	0.929	0.947	0.958	0.973	0.980	0.994	1.0
All	Forward	Pearson	0.750	0.810	0.878	0.915	0.947	0.968	0.983	0.991	0.998	1.0
		Spearman	0.745	0.806	0.876	0.911	0.946	0.966	0.981	0.991	0.997	1.0
	Reverse	Pearson	0.803	0.856	0.893	0.919	0.935	0.949	0.968	0.981	0.995	1.0
		Spearman	0.806	0.858	0.889	0.916	0.931	0.947	0.967	0.978	0.994	1.0

[1]Slick-cattle managed with slick bunk feed protocol, adlib-cattle had access to ad libitum feed, all–all groups were combined.

[2]Forward-records were split into the first F7, F14, F21, F28, F35, F42, F49, F56, F63, and F70 d of the test and reverse-records were split into the last R7, R14, R21, R28, R35, R42, R49, R56, R63, and R70 d of the test.

DMI surpassed 0.95 at 49 d in the Wang et al. (2006) study. Wang et al. (2006) also evaluated percent change in residual variation as test duration increased and determined that past 35 d, change in percent variation was less than 1%. Archer et al. (1997) reported a phenotypic correlation of 0.73 for a 35-d test duration, and at 49-d correlations surpassed 0.95. It is important that data on traits that are included in breeding objectives are accurately collected. Archer et al. (1997) wanted to determine if a shortened test duration would impact the efficiency of selection for DMI and determined that a shortened test duration of 35 d would not impact the efficiency of selection. The authors determined that test durations for DMI greater than 35 d would have very little improvement on accuracy of selection based on observing only a 0.04 gain in efficiency of selection when going from 35 to 70 d. Culbertson et al. (2015) reported that Pearson and Spearman correlations surpassed the 0.95 threshold at 42 d. Comparing results from ADG and DMI, it is likely that taking daily FI measurements provide more information to accurately calculate DMI, which in turn reduce test duration. Increased test duration for ADG may also be necessary to account for differences in rumen fill over time, when collecting measurements with more frequently is not feasible or practical. For group 1, the Pearson and Spearman correlations do not improve as rapidly after day 21 as the other groups. The rate of increase in the Pearson and Spearman correlations decreases between 35 to 42 d for group 3. This could be influenced by changes in weather during the feeding period for group 3. The first 35 d of the test duration were 6 °C cooler and averaged 7 cm more rain than the last 35 days. These changes in weather could have had an impact on DMI during the first week of hot and sunny weather, thus affecting the correlations. This is evident as all the other groups exhibited increased correlations as test durations moved closer to the full 70-d test period.

The Beef Improvement Federation guidelines (BIF, 2016) suggest a 45-d shortened test duration for FI, which is consistent with the results from our analysis. Normally, FI and gain are collected simultaneously and the test period for animals is determined by collection of gain data so feed conversion ratios can be calculated (Retallick et al., 2017). There is potential to decouple the collection of FI and gain by collecting FI phenotypes through a shortened test duration and using another measure of gain, such as postweaning ADG (Retallick et al., 2017). Postweaning ADG is determined by dividing the difference between weaning weight and yearling weight by the number of days elapsed between the two measurements (Retallick et al., 2017). However, to use this approach, both weaning and yearling weights must be available. Retallick et al. (2017) reported a genetic correlation between test ADG and postweaning ADG of 0.5 and 0.88 for steers and heifers, respectively. Using postweaning ADG would allow for FI to be collected within a shortened 35-d test, while still providing high-quality data for genetic evaluation. As an alternative to postweaning ADG, BW collected only at two time points (before and after the intake test) could be used to meet the 70-d suggested length; regardless, BW while on test can be used in a multiple trait approach with postweaning gain and test intake as suggested by Thallman et al. (2018). This approach could potentially also be applied to phenotypes for WI, provided that the required test duration is similar.

WI Test Duration

Means and their corresponding SD for WI for subsets and the entire 70-d test period are shown in Table 6, and illustration of means for all animals is presented in Fig. 1B. As test duration increases for groups 1, 2, 3, and 5, the amount of water consumed increases numerically. Water consumption would be expected to increase as animals increase in size and BW during the testing period. In addition, groups 1 and 3 likely increase their water consumption due to a 1.5 °C (group 1) and 6 °C (group 3) increase in temperature from the first 35 d to the last 35 d. As ambient temperature rises, animals become more dependent upon peripheral vasodilation and water evaporation to increase heat loss and keep body temperature from rising (Berman et al., 1985), which could result in greater water requirements. In group 4, WI peaks around days 28 to 42, then decreases through the end of the test period. The results for WI differ when comparing calculations from the beginning (F7–F70) and end of the test (R7–R70), most likely because of the impact of temperature variation (21.6 to 31.9 °C) on WI, in addition to the impact of body mass. For the shortest test duration in the reverse analyses, cattle BWs are heavier, as animals

Table 6. Means (SD) for a 70-d daily water intake (WI, kg) test[1]

		Day of test									
Group	Direction[2]	7	14	21	28	35	42	49	56	63	70
1	Forward	31.8 (9.7)	34.5 (8.9)	35.5 (8.4)	37.4 (8.4)	38.5 (8.4)	38.6 (8.3)	39.1 (7.9)	39.3 (7.8)	40.1 (7.9)	40.6 (8.1)
	Reverse	45.6 (11.9)	45.4 (10.6)	43.9 (9.6)	43.6 (9.3)	42.7 (8.9)	42.7 (8.8)	42.7 (8.7)	42.1 (8.6)	41.4 (8.3)	40.6 (8.1)
2	Forward	24.7 (7.1)	24.6 (6.5)	24.7 (6.4)	25.2 (6.3)	25.7 (6.1)	26.3 (6.2)	26.3 (6.0)	26.3 (5.8)	26.6 (5.6)	27.3 (5.4)
	Reverse	33.7 (12.4)	30.1 (10.7)	29.5 (7.4)	29.1 (6.3)	29.1 (5.9)	28.8 (5.7)	28.4 (5.7)	28.0 (5.6)	27.6 (5.5)	27.3 (5.4)
3	Forward	27.9 (7.1)	28.0 (6.7)	27.6 (6.3)	28.5 (6.3)	31.2 (6.3)	32.3 (6.2)	34.6 (6.5)	35.5 (6.6)	36.3 (6.7)	35.9 (6.6)
	Reverse	33.5 (7.7)	37.7 (8.5)	39.9 (8.3)	41.2 (8.3)	41.0 (8.2)	41.0 (8.0)	39.4 (7.5)	37.9 (7.0)	36.8 (6.8)	35.9 (6.6)
4	Forward	44.9 (9.3)	48.4 (11.2)	51.3 (12.9)	51.6 (13.4)	53.9 (14.5)	53.2 (14.3)	52.6 (13.9)	53.0 (14.3)	52.4 (14.1)	51.5 (13.8)
	Reverse	44.0 (12.9)	45.6 (12.4)	49.0 (14.3)	48.9 (13.5)	49.2 (13.5)	51.4 (14.5)	51.8 (14.7)	52.3 (14.8)	52.2 (14.4)	51.5 (13.8)
5	Forward	29.2 (5.2)	29.8 (4.9)	30.9 (4.9)	31.6 (4.9)	32.9 (5.0)	33.4 (4.9)	33.9 (4.9)	34.2 (4.9)	34.5 (4.8)	34.7 (4.8)
	Reverse	36.6 (6.5)	36.4 (5.5)	36.5 (5.3)	36.8 (5.3)	36.6 (5.2)	36.8 (5.2)	36.4 (5.1)	35.9 (5.0)	35.2 (4.8)	34.7 (4.8)
All	Forward	31.4 (10.3)	32.7 (11.2)	33.6 (12.1)	34.5 (12.2)	36.0 (12.7)	36.3 (12.2)	37.0 (11.8)	37.3 (11.9)	37.7 (11.7)	37.7 (11.3)
	Reverse	38.5 (11.6)	38.9 (11.3)	39.6 (11.3)	39.7 (11.0)	39.5 (11.3)	39.9 (11.5)	39.5 (11.6)	39.0 (11.7)	38.3 (11.6)	37.7 (11.3)

[1]Shorter test durations are subsets of the full 70-d tests of the specified duration. Forward analyses begin at day 0 and reverse analyses begin at day 70.

[2]Forward-records were split into the first F7, F14, F21, F28, F35, F42, F49, F56, F63, and F70 d of the test and reverse-records were split into the last R7, R14, R21, R28, R35, R42, R49, R56, R63, and R70 d of the test.

are largest at the end of the test. For the summer groups (1, 3 and 4), temperature increased from the start of the trial until the end of the test period. The winter groups (2 and 5) were extremely variable, and temperatures fluctuated from around 15 °C at the start of the trial to −1 °C (group 2) and 25 °C (group 5). WI for groups 1 and 2 decreased from R7 to R70. Group 5 mean intakes were similar from R7 to R49, with a slight decrease in WI after R56.

The first 7 d of the study for groups 1, 4, as well as for data combined across groups, had larger SD among animals within a group than groups 2, 3, and 5. As the test duration increased for groups 1 and 4, the variation in WI among animals within each group decreased. As test duration increases (F7–F70), variation among each group tends to decrease. However, as test duration increases in the reverse direction, only small changes in variation are observed as cattle spend more days on test. Greater variation is seen for the shorter test durations in the summer groups (1, 3, and 4) than the winter groups (2 and 5). This is likely due to weather factors influencing the variation in WI within the summer groups. Winter group steers experienced varying degrees of cold stress, whereas steers fed during the summer experienced varying degrees of heat stress, which can have an impact on WI. Summer groups experienced a different number of days when THI exceeded 74 during the 70-d trial period (group 1, 38 d; group 3, 32 d; and group 4, 62 d).

Pearson and Spearman correlations for subsets and the full 70-d test period are presented in Table 7

Table 7. Pearson and Spearman correlations for each shortened test duration and the full 70-d test period for water intake (WI, kg)

			Day of test									
Group[1]	Direction[2]	Analysis	7	14	21	28	35	42	49	56	63	70
1	Forward	Pearson	0.635	0.733	0.821	0.881	0.927	0.955	0.978	0.988	0.996	1.0
		Spearman	0.591	0.696	0.778	0.837	0.899	0.943	0.973	0.985	0.995	1.0
	Reverse	Pearson	0.831	0.888	0.913	0.922	0.935	0.954	0.973	0.984	0.996	1.0
		Spearman	0.848	0.883	0.903	0.917	0.936	0.955	0.970	0.982	0.994	1.0
2	Forward	Pearson	0.722	0.794	0.838	0.879	0.906	0.920	0.927	0.935	0.981	1.0
		Spearman	0.612	0.735	0.799	0.836	0.871	0.885	0.900	0.911	0.975	1.0
	Reverse	Pearson	0.448	0.462	0.652	0.783	0.889	0.932	0.964	0.984	0.995	1.0
		Spearman	0.452	0.461	0.647	0.777	0.871	0.916	0.957	0.981	0.994	1.0
3	Forward	Pearson	0.727	0.787	0.806	0.823	0.906	0.946	0.972	0.986	0.998	1.0
		Spearman	0.706	0.775	0.799	0.822	0.907	0.945	0.973	0.986	0.997	1.0
	Reverse	Pearson	0.766	0.850	0.905	0.935	0.942	0.953	0.978	0.989	0.997	1.0
		Spearman	0.795	0.851	0.915	0.938	0.950	0.957	0.977	0.988	0.997	1.0
4	Forward	Pearson	0.822	0.887	0.944	0.967	0.985	0.989	0.994	0.997	0.999	1.0
		Spearman	0.867	0.914	0.945	0.957	0.979	0.987	0.992	0.996	0.998	1.0
	Reverse	Pearson	0.879	0.940	0.967	0.973	0.982	0.988	0.992	0.996	0.999	1.0
		Spearman	0.845	0.927	0.956	0.961	0.971	0.978	0.989	0.996	0.999	1.0
5	Forward	Pearson	0.835	0.868	0.895	0.923	0.947	0.967	0.983	0.991	0.996	1.0
		Spearman	0.819	0.848	0.889	0.924	0.951	0.964	0.979	0.990	0.996	1.0
	Reverse	Pearson	0.694	0.863	0.910	0.919	0.940	0.966	0.982	0.992	0.997	1.0
		Spearman	0.634	0.833	0.886	0.907	0.935	0.962	0.979	0.989	0.995	1.0
Slick	Forward	Pearson	0.705	0.805	0.845	0.879	0.935	0.957	0.977	0.984	0.995	1.0
		Spearman	0.669	0.783	0.818	0.858	0.928	0.955	0.977	0.984	0.995	1.0
	Reverse	Pearson	0.686	0.818	0.902	0.931	0.945	0.958	0.980	0.991	0.998	1.0
		Spearman	0.638	0.800	0.904	0.936	0.953	0.963	0.982	0.991	0.998	1.0
Adlib	Forward	Pearson	0.894	0.930	0.960	0.975	0.986	0.991	0.995	0.997	0.999	1.0
		Spearman	0.932	0.947	0.960	0.970	0.980	0.987	0.993	0.996	0.998	1.0
	Reverse	Pearson	0.827	0.919	0.960	0.965	0.975	0.986	0.991	0.996	0.999	1.0
		Spearman	0.665	0.829	0.914	0.926	0.944	0.972	0.987	0.995	0.999	1.0
All	Forward	Pearson	0.830	0.892	0.921	0.941	0.966	0.977	0.988	0.992	0.997	1.0
		Spearman	0.793	0.858	0.876	0.903	0.947	0.966	0.983	0.989	0.997	1.0
	Reverse	Pearson	0.712	0.822	0.920	0.933	0.950	0.970	0.985	0.994	0.999	1.0
		Spearman	0.639	0.792	0.899	0.923	0.943	0.963	0.982	0.993	0.998	1.0

[1]Slick-cattle managed with slick bunk feed protocol, adlib-cattle had access to ad libitum feed, all–all groups were combined.

[2]Forward-records were split into the first F7, F14, F21, F28, F35, F42, F49, F56, F63, and F70 d of the test and reverse-records were split into the last R7, R14, R21, R28, R35, R42, R49, R56, R63, and R70 d of the test.

Table 8. Pearson and Spearman correlation confidence intervals for each shortened test duration for daily water intake (WI, kg)

			Test duration, d								
Group[1]	Direction[2]	Analysis	7	14	21	28	35	42	49	56	63
1	Forward	Pearson	0.513–0.732	0.636–0.807	0.751–0.872	0.833–0.916	0.897–0.949	0.935–0.968	0.968–0.985	0.982–0.991	0.995–0.997
		Spearman	0.459–0.697	0.589–0.779	0.694–0.840	0.774–0.884	0.858–0.929	0.919–0.960	0.962–0.981	0.979–0.990	0.993–0.997
	Reverse	Pearson	0.766–0.880	0.842–0.921	0.877–0.939	0.889–0.945	0.908–0.955	0.934–0.968	0.961–0.981	0.977–0.989	0.995–0.997
		Spearman	0.787–0.891	0.836–0.916	0.863–0.932	0.882–0.941	0.909–0.955	0.936–0.968	0.957–0.979	0.974–0.987	0.993–0.997
2	Forward	Pearson	0.617–0.796	0.713–0.852	0.772–0.884	0.828–0.914	0.867–0.934	0.886–0.944	0.894–0.948	0.906–0.954	0.972–0.986
		Spearman	0.473–0.708	0.630–0.804	0.704–0.847	0.766–0.881	0.808–0.903	0.835–0.917	0.856–0.928	0.871–0.936	0.964–0.983
	Reverse	Pearson	0.290–0.583	0.306–0.594	0.542–0.751	0.719–0.855	0.848–0.924	0.906–0.954	0.950–0.976	0.977–0.959	0.993–0.997
		Spearman	0.294–0.586	0.304–0.593	0.538–0.749	0.716–0.853	0.824–0.912	0.880–0.941	0.938–0.970	0.972–0.986	0.991–0.995
3	Forward	Pearson	0.629–0.802	0.707–0.847	0.732–0.861	0.755–0.874	0.867–0.934	0.924–0.962	0.960–0.980	0.980–0.991	0.997–0.999
		Spearman	0.603–0.786	0.692–0.838	0.723–0.856	0.753–0.873	0.869–0.934	0.922–0.962	0.961–0.981	0.980–0.990	0.995–0.998
	Reverse	Pearson	0.679–0.831	0.792–0.894	0.867–0.933	0.907–0.954	0.917–0.959	0.933–0.967	0.968–0.984	0.984–0.992	0.996–0.998
		Spearman	0.718–0.853	0.792–0.894	0.880–0.940	0.912–0.967	0.929–0.970	0.938–0.970	0.967–0.984	0.983–0.992	0.995–0.998
4	Forward	Pearson	0.748–0.875	0.837–0.922	0.919–0.962	0.952–0.978	0.978–0.989	0.984–0.993	0.991–0.995	0.995–0.998	0.998–0.999
		Spearman	0.810–0.908	0.876–0.941	0.920–0.962	0.937–0.970	0.969–0.986	0.981–0.991	0.988–0.994	0.994–0.997	0.997–0.999
	Reverse	Pearson	0.827–0.916	0.913–0.959	0.951–0.977	0.960–0.981	0.974–0.988	0.982–0.992	0.988–0.994	0.994–0.997	0.998–0.999
		Spearman	0.780–0.892	0.894–0.949	0.936–0.970	0.943–0.973	0.959–0.980	0.968–0.985	0.984–0.992	0.993–0.997	0.998–0.999
5	Forward	Pearson	0.773–0.882	0.816–0.906	0.854–0.926	0.892–0.946	0.925–0.962	0.953–0.977	0.975–0.988	0.987–0.994	0.994–0.997
		Spearman	0.751–0.870	0.789–0.891	0.846–0.921	0.894–0.947	0.930–0.965	0.949–0.975	0.971–0.986	0.985–0.993	0.994–0.997
	Reverse	Pearson	0.589–0.775	0.810–0.902	0.874–0.934	0.886–0.943	0.916–0.958	0.951–0.976	0.974–0.987	0.988–0.994	0.996–0.998
		Spearman	0.514–0.729	0.779–0.880	0.842–0.919	0.869–0.934	0.908–0.954	0.945–0.973	0.970–0.850	0.985–0.993	0.993–0.997
Slick	Forward	Pearson	0.658–0.754	0.765–0.839	0.812–0.872	0.852–0.900	0.920–0.947	0.948–0.965	0.972–0.981	0.980–0.987	0.994–0.996
		Spearman	0.606–0.722	0.739–0.821	0.781–0.850	0.827–0.883	0.912–0.942	0.944–0.963	0.971–0.981	0.980–0.987	0.994–0.996
	Reverse	Pearson	0.626–0.737	0.780–0.850	0.881–0.920	0.916–0.944	0.932–0.955	0.948–0.966	0.975–0.984	0.988–0.992	0.997–0.998
		Spearman	0.572–0.696	0.759–0.834	0.884–0.922	0.922–0.948	0.942–0.962	0.954–0.970	0.977–0.985	0.989–0.993	0.997–0.998
Adlib	Forward	Pearson	0.865–0.918	0.910–0.946	0.948–0.967	0.967–0.980	0.981–0.989	0.987–0.992	0.993–0.995	0.996–0.997	0.998–0.999
		Spearman	0.913–0.948	0.932–0.959	0.949–0.969	0.961–0.977	0.974–0.985	0.983–0.990	0.991–0.994	0.995–0.997	0.998–0.999
	Reverse	Pearson	0.781–0.864	0.896–0.937	0.948–0.969	0.955–0.973	0.968–0.981	0.982–0.989	0.988–0.993	0.995–0.997	0.999–1.0
		Spearman	0.586–0.732	0.784–0.866	0.889–0.933	0.905–0.942	0.928–0.956	0.964–0.978	0.982–0.990	0.993–0.996	0.998–0.999
All	Forward	Pearson	0.803–0.854	0.874–0.907	0.908–0.932	0.931–0.950	0.960–0.971	0.973–0.980	0.986–0.990	0.990–0.993	0.997–0.998
		Spearman	0.760–0.821	0.835–0.878	0.846–0.894	0.886–0.917	0.938–0.955	0.960–0.971	0.980–0.986	0.987–0.991	0.996–0.997
	Reverse	Pearson	0.669–0.749	0.794–0.847	0.906–0.932	0.922–0.943	0.941–0.957	0.965–0.974	0.982–0.987	0.993–0.995	0.998–0.999
		Spearman	0.588–0.684	0.760–0.821	0.883–0.914	0.911–0.935	0.933–0.951	0.957–0.969	0.979–0.985	0.991–0.994	0.997–0.998

[1]Slick-cattle managed with slick bunk feed protocol, adlib-cattle had access to ad libitum feed, all–all groups were combined.

[2]Forward-records were split into the first F7, F14, F21, F28, F35, F42, F49, F56, and F63 d of the test and reverse-records were split into the last R7, R14, R21, R28, R35, R42, R49, R56, and R63 d of the test.

and graphically illustrated in Supplementary Fig. S3. Confidence intervals for subsets and the full 70-d test period are presented in Table 8. Although variation exists within individual groups, the Pearson correlations for data combined across all groups indicate that a minimum of 35 d of data are necessary for collection of accurate WI phenotypes. Cattle that were managed with the slick bunk feed protocol required a slightly longer test duration of 42 d, regardless of whether the analysis was conducted from the beginning or end of the test. However, the Pearson and Spearman correlations in the reverse direction were not significantly different from 0.95 at 35 d. However, results from the adlib fed groups indicated that a shorter test duration of approximately 21 d would be acceptable. Spearman correlations for each group follow a similar pattern to the Pearson correlations, except for the Spearman correlations in the reverse analysis, which did not meet the threshold of 0.95 until 42 d (correlations were not significantly different from 0.95 at 35 d). For cattle fed during the summer (groups 1, 3, and 4), the first half of the test period was during May and June and the second half of the test took place during July and into August. The first half of the test tended to be slightly cooler (24.57 °C, 20.24 °C, and 27.33 °C, for groups 1, 3, and 4, respectively) than in the second half of the test period (25.49 °C, 26.46 °C, and 28.79 °C, for groups 1, 3, and 4, respectively).The temperature changes were likely a contributing factor to the observation that cattle consumed less water and intakes were less variable in the first half of the test period as compared to the last half of the test period.

For WI, the Pearson correlation threshold of 0.95 is exceeded by 35 d, regardless of whether the values were calculated from the beginning or end of test (0.966 and 0.95 for F35 and R35, respectively). Unlike DMI, the Spearman correlations are slightly lower at the same number of days (F35 = 0.947 and R35 = 0.943) and do not exceed the threshold of 0.95. This difference indicates that there is more re-ranking of individuals for WI than for DMI at the same test length threshold. Thus, if re-ranking of individuals is a concern, the test period should likely be extended to at least 42-d. Increasing this threshold is not problematic, as it is unlikely that animals would be undergoing a WI test that was not concurrent with a FI test, which would generally be at least 42 to 45 d.

CONCLUSION

The results from the current study suggest 70- and 42-d test durations are required for accurate collection of ADG and DMI phenotypes, respectively. This recommendation is similar to several studies previously published in the scientific literature. This analysis also suggests that WI can be collected over a 35- to 42-d test. Results for DMI and WI indicate that both phenotypes can be collected simultaneously with a shortened test duration of 42 d, which would not interfere with the potential for decoupling FI and gain performance tests. These results were generated using data that spans a variety of seasons and animals from a variety of backgrounds. However, they are calculated using data from a single facility; thus, these results should be evaluated in other locations or results should be combined in a meta-analysis of multiple datasets as they become available to make a final recommendation on WI test length. Concurrent collection of both WI and DMI phenotypes allows more cost-effective phenotypic data collection and increases the utility of FI tests by collecting an additional phenotype for the same cost, provided the facility has the capability to collect WI.

SUPPLEMENTARY DATA

Supplementary data are available at *Journal of Animal Science* online.

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