Technical Note: Do dietary net energy values calculated from performance data offer increased sensitivity for detecting treatment differences?

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ABSTRACT: A simulation technique involving 100 hypothetical experiments (24 pens each for control and treated groups) for each of 3 cases was used to evaluate the statistical sensitivity of dietary NE concentrations calculated from performance data. In case 1, the treated population had a 12-kg increase in mean shrunk final BW (FBW) and no change in DMI; in case 2, the treated population had a 19-kg increase in mean shrunk FBW and 0.25-kg increase in DMI; and in case 3, the treated population had a 0.43-kg decrease in DMI and no change in ADG. In all 3 cases, cattle were assumed to be fed for 150 d, and changes in the treated group resulted in a similar increase in G:F (approximately 5%). Population means and SD for initial and final BW and DMI were used to generate 100 experiments based on normal distribution equations, and resulting BW and DMI values were used to calculate dietary NE_m and NE_g concentrations required to yield the observed performance. The BW, ADG, DMI, G:F, and NE values for control and treated samples were statistically compared within each experiment, with significance declared at $P \leq 0.05$. In case 1, FBW differed in 96% of the experiments, whereas the DMI and ADG differed in 3 and 87% of the experiments, respectively. The G:F differed ($P \leq 0.05$) in 63% of the experiments, but NE concentrations differed in only 42% of the experiments. In case 2, FBW differed between control and treatment in 100% of the experiments, whereas DMI and G:F differed in 53 and 52% of the experiments, respectively. Similar to FBW, ADG was greater for treated pens in 100% of the experiments, but dietary NE values differed in only 23% of the experiments. In case 3, FBW differed in 3%, DMI differed in 91%, and ADG differed in 3% of the experiments. In contrast to results with cases 1 and 2, differences in G:F were observed in 55% of the experiments compared with differences in 78% of the experiments for calculated NE values. These data suggest that the performance variable that drove changes in NE values (e.g., DMI or changes in BW) was a more sensitive measure of treatment effects than calculated NE dietary values. Dietary NE values calculated from performance data can be useful for describing treatment effects, but they do not generally seem to offer statistical advantages in sensitivity over the performance variables from which they are derived.

Key words: body weight, cattle, feed intake, feedlot, gain:feed, net energy

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INTRODUCTION

Equations provided in the NRC (1996) nutrient requirements publication for beef cattle allow for determination of the NE required for maintenance and gain (NE_m and NE_g, respectively). Assuming that the observed DMI can be partitioned into the portion required to support maintenance, with the remainder available for gain, BW and ADG data can be used to determine the NE_m and NE_g concentration in the diet that would be required to yield the observed performance data (Zinn et al., 2003). Calculation of dietary NE values in this manner has become commonplace in applied animal nutrition studies, and the resulting NE_m and NE_g data are often analyzed statistically (e.g., Plascencia et al., 1999; Ramirez and Zinn, 2000; Zinn et al., 2000, 2003). Although these calculated NE values can be useful for determining whether treatments affect energy utilization or can be used to determine the NE concentrations of novel feedstuffs, their sensitivity for detecting treatment differences compared with performance data has not been evaluated. Our objective was to use a simulation technique to evaluate the statistical sensitivity of dietary NE concentrations calculated from

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performance data compared with the performance data from which the NE values were derived.

MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because no animals were used.

Three different cases (scenarios) were simulated. In each case, 100 hypothetical experiments involving 48 pens of cattle (24 each of control and treated) were evaluated. Means and SD for BW and DMI used in the simulation were based on data from experiments conducted at the Texas Tech University Burnett Center over a period of several years. In these experiments, a pen of cattle (5 animals/pen) was the experimental unit. Cattle were British and British × Continental crossbreds that were typically yearlings fed for 130 to 160 d to a final BW that would provide sufficient finish for the cattle to achieve a USDA quality grade of Choice. Population means and SD were set for initial shrunk BW (**IBW**), final shrunk BW (**FBW**), and DMI. In all 3 cases, the cattle were assumed to be fed for 150 d. Population values for dietary NE_m and NE_g were calculated based on population means for IBW and FBW (and resulting shrunk ADG), and DMI values. An Excel (Microsoft Corp., Redmond, WA) spreadsheet function (NORMINV) was used to generate the 100 hypothetical experiments by seeding the NORMINV function with a randomly selected probability value between 0 and 1 (using the RAND function of Excel) along with the assumed population mean and SD [e.g., for each case, the Excel command line for initial BW would read: = NORMINV(RAND(), 350, 7), where the RAND function generates a random number between 0 and 1, and 350 and 7 are the population mean and SD, respectively]. For each experiment, 24 random samples were generated for the variables IBW, FBW, and DMI for both control and treated groups (48 pens total), after which ADG, G:F, and dietary NE concentrations were calculated. Population means and SD for the 3 cases are shown in Table 1. Briefly, in case 1, treated pens had a 12-kg increase in mean shrunk FBW and no change in DMI; in case 2, treated pens had a 19-kg increase in mean shrunk FBW and 0.25-kg increase in DMI; and in case 3, treated pens had a 0.43-kg decrease in DMI and no change in FBW. Thus, each case resulted in essentially the same change in G:F (approximately 5%), but the way in which this change in G:F occurred differed with each case. Dietary NE_m and NE_g concentrations were calculated via a quadratic solution as described by Zinn et al. (2003); however, the equivalent BW scaling approach of NRC (1996) was used rather than the medium-framed steer equations for NRC (1984). Cattle were assumed to have a target endpoint of Choice (e.g., standard reference weight = 478 kg) for the calculation of equivalent BW.

Performance and calculated NE values were compared statistically by analyzing the data for each of the 100 experiments as a completely random design in Proc Mixed of SAS (SAS Inst. Inc., Cary, NC). Because the SD for the variables analyzed were the same for the control and treated populations, the assumption of homoscedasticity was not tested. Statistically significant ($P \leq 0.05$) differences between the means of control and treated samples were detected using the ANOVA *F*-test in Proc Mixed.

RESULTS AND DISCUSSION

Mean data for the 100 hypothetical experiments for each of the 3 cases are summarized in Table 2. As expected, with adequate replication and simulation of a relatively large number of experiments, the overall means and SD for control and treated groups from the 100 hypothetical experiments were very similar to the underlying population values (e.g., compare the sample and SD values in Table 2 with the population mean and SD values in Table 1). Table 3 shows the percentage of experiments in which there was a significant ($P \leq 0.05$) difference between control and treated groups across the 100 experiments. To facilitate discussion, the data in Table 3 will be considered for each case.

Table 1. Means of population data used for hypothetical experiments (n = 100) used for statistical comparison between control and treated samples

Item	Treatment group[1]	Initial BW	Final BW	DMI	ADG	G:F	NE_m[2]	NE_g[2]
Case 1	Control	350.0	584.0	8.95	1.560	0.1743	2.14	1.47
	Treated	350.0	596.0	8.95	1.640	0.1832	2.20	1.52
	SD	7	11.7	0.45	—	—	—	—
Case 2	Control	350.0	584.0	8.95	1.560	0.1743	2.14	1.47
	Treated	350.0	603.0	9.20	1.687	0.1834	2.19	1.51
	SD	7	11.7	0.45	—	—	—	—
Case 3	Control	350.0	584.0	8.95	1.560	0.1743	2.14	1.47
	Treated	350.0	584.0	8.52	1.560	0.1831	2.24	1.55
	SD	7	11.7	0.45	—	—	—	—

[1]Case 1: treated pens had a 12-kg increase in mean shrunk final BW and no change in DMI; case 2: treated pens had a 19-kg increase in mean shrunk FBW and 0.25-kg increase in DMI; and case 3: treated pens had a 0.43-kg decrease in DMI and no change in ADG.

[2]Dietary NE_m and NE_g values were calculated based on the NE requirement equations of NRC (1996).

Table 2. Means and standard deviations of hypothetical experiments (n = 100) used for statistical comparison between control and treated samples

Item[1]	Control	Treated
Case 1		
Initial BW, kg	349.99 ± 7.05	350.09 ± 6.84
Final BW, kg	584.05 ± 11.75	596.29 ± 11.65
DMI, kg	8.945 ± 0.439	8.946 ± 0.448
ADG, kg	1.560 ± 0.092	1.641 ± 0.089
G:F	0.175 ± 0.013	0.184 ± 0.014
NE_m[2]	2.148 ± 0.112	2.211 ± 0.118
NE_g[2]	1.474 ± 0.098	1.529 ± 0.103
Case 2		
Initial BW, kg	349.93 ± 6.90	350.08 ± 6.98
Final BW, kg	584.06 ± 11.58	602.51 ± 11.55
DMI, kg	8.954 ± 0.458	9.213 ± 0.448
ADG, kg	1.561 ± 0.088	1.683 ± 0.092
G:F	0.175 ± 0.013	0.183 ± 0.013
NE_m[2]	2.146 ± 0.113	2.187 ± 0.111
NE_g[2]	1.472 ± 0.099	1.508 ± 0.097
Case 3		
Initial BW, kg	349.90 ± 7.11	350.10 ± 6.85
Final BW, kg	583.62 ± 11.71	583.96 ± 11.58
DMI, kg	8.953 ± 0.451	8.530 ± 0.447
ADG, kg	1.558 ± 0.091	1.559 ± 0.091
G:F	0.174 ± 0.013	0.183 ± 0.014
NE_m[2]	2.144 ± 0.113	2.237 ± 0.123
NE_g[2]	1.471 ± 0.099	1.552 ± 0.108

[1]Case 1: treated pens had a 12-kg increase in mean shrunk final BW and no change in DMI; case 2: treated had a 19-kg increase in mean shrunk FBW and 0.25-kg increase in DMI; and case 3: treated pens had a 0.43-kg decrease in DMI and no change in ADG.

[2]Calculated based on the NE requirement equations of NRC (1996).

Table 3. Percentage of experiments (n = 100) in which a statistical difference ($P \leq 0.05$) between control and treated groups was observed

Item	Case[1,2] 1	2	3
Initial BW, kg			
Significant differences, %	6.0	5.0	9.0
Final BW, kg			
Significant differences, %	96.0	100.0	3.0
DMI, kg			
Significant differences, %	3.0	53.0	91.0
ADG, kg			
Significant differences, %	87.0	100.0	3.0
G:F			
Significant differences, %	63.0	52.0	55.0
NE_m[3]			
Significant differences, %	42.0	23.0	78.0
NE_g[3]			
Significant differences, %	42.0	23.0	78.0

[1]Case 1: treated pens had a 12-kg increase in mean shrunk final BW; case 2: treated had a 19-kg increase in mean shrunk FBW and 0.25-kg increase in DMI; case 3: treated pens had a 0.43-kg decrease in DMI.

[2]Each case compared the statistical results of 100 hypothetical experiments (24 pens each for control and treated groups).

[3]Calculated based on the NE requirement equations of NRC (1996).

Case 1

Case 1 was a situation in which the G:F was increased approximately 5% through a change in final BW (and thereby ADG), with no change in DMI. Initial BW differed in 6% of the experiments in case 1, which represents the occurrence of type I errors. Final BW differed in 96% of the experiments, which would be expected because the data were randomly selected from control and treated populations that differed by 12 kg in FBW. The DMI differed in 3% of the experiments (type I errors), and ADG differed in 87% of the experiments. The high sensitivity for ADG would be expected because with constant days on feed, ADG would mirror differences in FBW. Moreover, reflecting the increased ADG by the treated group, G:F differed in 63% of the experiments. Both NE_m and NE_g were less sensitive for detecting treatment differences than ADG and G:F, with only 42% of the experiments showing a difference between control and treated groups for the NE concentrations.

Case 2

Initial BW differed in 5% of the experiments in case 2, again reflecting the occurrence of type I errors. This spreadsheet-based simulation approach provides an excellent method of depicting type I and type II errors and would provide a useful means of illustrating these points in classroom settings. Final BW differed in 100% of the experiments (samples were obtained from a population in which treated pens had an increased FBW of 19 kg), with the same SD as in case 1, for which the increased FBW was only 12 kg. Although DMI was increased by 0.25 kg in the treated population, DMI differed in only 53% of the experiments, which reflects the greater SD relative to the mean (i.e., CV) for DMI than for FBW in this simulation. Because of the large increase in FBW, ADG was greater for the treated group in 100% of the experiments. Nonetheless, differences were observed in only 52% of the experiments for G:F, a slightly lesser sensitivity to treatment differences than in case 1, for which FBW was increased by only 12 kg in the treated group, but DMI was not changed. Also, in contrast to the results of case 1, dietary NE_m and NE_g concentrations differed in only 23% of the experiments.

Case 3

In case 3, IBW differed in 9% of the experiments, again illustrating the real potential for type I errors, even in substantially replicated experiments. Final BW differed in only 3% of the experiments; a low value was expected given that the population values for control and treated groups were the same for FBW. The DMI differed in 91% of the experiments, reflecting the decrease of 0.43 kg in DMI in the treated population. Similar to results with FBW, differences in ADG were observed in only 3% of the experiments; however, differences in G:F were observed in 55% of the experiments, which is similar to the sensitivity noted for G:F in case 1. In contrast to cases 1 and 2, NE_m and NE_g values differed in 78% of the experiments, suggesting that calculated NE concentrations might be more sensitive to treatment differences than G:F in cases where a decrease in DMI is the sole factor that drives the change in the NE concentrations.

Overall, these results suggest that the sensitivity to detect treatment effects using dietary NE values calculated from performance data depends on the changes in performance data that drive the changes in the NE values. For example, in case 1, increased FBW with no change in DMI resulted in treatment differences between dietary NE values in 42% of the experiments. In contrast, a greater increase in FBW associated with a modest increase in DMI yielded fewer significant treatment differences in NE concentrations (23% of the experiments) in case 2. In cases 1 and 2, the performance factor responsible for the change in NE concentrations (primarily changes in FBW and thereby ADG in both cases) was more sensitive to treatment differences than NE concentrations. The somewhat lower sensitivity observed for NE values in case 2 compared with case 1 reflects the fact that although ADG increased to a greater extent in case 2 than in case 1, DMI also was increased by treatment in case 2.

Results with case 3 suggest that changing NE concentrations by decreasing DMI had the greatest effect on the statistical sensitivity for detecting treatment differences in dietary NE values, with statistical differences in 78% of the experiments. Nonetheless, DMI itself differed in 91% of the experiments, suggesting that the factor responsible for the change in NE concentrations (e.g., ADG or DMI) will be a more sensitive indicator of treatment effects than calculated NE concentrations. Dietary NE concentrations calculated from performance data are more sensitive to changes in DMI than to changes in ADG (e.g., case 3 vs. case 1), with the largest change in calculated NE_m and NE_g concentrations occurring with case 3 (Table 1). This result can be explained mathematically by the basic formula used in our calculations. Given that total DMI can be divided into DMI for maintenance plus DMI for gain, total DMI can be expressed as follows:

$$\text{Total DMI} = (NE_m \text{ required}/NE_m \text{ concentration}) + (NE_g \text{ required}/NE_g \text{ concentration}),$$

where DMI for maintenance and DMI for gain are expressed in terms of animal requirements for NE_m and NE_g (Mcal/d) divided by their respective dietary NE concentrations (Mcal/unit of DM). The numerators on the right-hand side of the equation (NE_m and NE_g requirements) are solely a function of BW and ADG. Thus, if a treatment changes ADG, and DMI remains the same as in case 1, the numerators and denominators in the right-hand side of the equation will be increased. In contrast, if DMI changes, and ADG remains the same as in case 3, only the denominators (NE concentrations) on the right-hand side of the equation change between the control and treated groups. Thus, treatments that cause a change in the NE value via decreased DMI result in the greatest change in calculated NE values, even though G:F might be virtually identical to cases in which only ADG or both ADG and DMI were altered by treatment (as in cases 1 and 2). As a result, the sensitivity for detecting treatment differences in calculated NE concentrations would be expected to be greater in cases where DMI is the sole factor driving the change in NE concentrations, as in case 3 in our simulation.

Standard deviations and means for G:F, NE_m, and NE_g in Table 2 can be used to calculate the CV for these variables. It is noteworthy that the average CV for G:F (7.52, 7.27, and 7.56 for case 1, 2, and 3, respectively) was greater than the CV for NE_m (5.27, 5.18, and 5.39, respectively) and NE_g (6.70, 6.58, and 6.85, respectively). Despite a consistently lower CV for the NE values, only in case 3 were NE values more sensitive than G:F for detecting treatment differences. This finding reflects the fact that both the magnitude of the difference between control and treated groups and the CV determine the sensitivity to detect treatment differences, a point illustrated by Berndtson (1991) to calculate the sample size required to detect a given percent difference for a given CV. Thus, although the CV was greater for G:F than for NE_m in all 3 cases, the difference between control and treated groups was greater for G:F (5.11, 5.22, and 5.05% for G:F vs. 2.80, 2.34, and 4.67% for NE_m in cases 1, 2, and 3, respectively). These data are consistent with our findings for case 3, in which the largest difference among the 3 cases between control and treated groups was observed for both NE_m and NE_g, and the calculated NE values also yielded a greater percentage of experiments in which an effect of treatment was detected.

Our results suggest that dietary NE values calculated from performance data depend on the changes in performance variables on which they are based. Treatments that decrease DMI with no change in ADG would be expected to result in maximal changes in calculated NE concentrations. In the 3 simulations we examined, the performance variable that drove changes in NE values (e.g., DMI or changes in FBW and thereby ADG) was a more sensitive measure of treatment effects than calculated NE dietary values. Researchers should be encouraged to calculate dietary NE values from performance data because these values can be useful for describing treatment effects and for determining the energy values of novel feedstuffs. Moreover, statistical evaluation of such values to assess variability in the resulting NE estimates is advised. Nonetheless, based on the results of our simulation exercise, calculated NE concentrations do not generally offer statistical advantages in sensitivity over the performance variables from which they are derived.

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