# Effects of diet digestibility on feed efficiency and impact of diet type and feeding phase on repeatability of feed efficiency phenotype

*S. L. Hansen, *[2] J. R. Russell,* N. O. Minton,† W. J. Sexten,† M. S. Kerley,† E. L. Lundy,* E. K. Niedermayer, * and National Program for Genetic Improvement of Feed Efficiency in Beef Cattle‡*

* Department of Animal Science, Iowa State University, Ames 50011
† Division of Animal Sciences, University of Missouri, Columbia 65211
‡ The names and affiliations of scientists working with the National Program for Genetic Improvement of Feed Efficiency in Beef Cattle are listed at http://www.beefefficiency.org/about.html
[1]Funding provided by USDA NIFA grant #2011-68004-30214
[2] Corresponding author: slhansen@iastate.edu

## Introduction

Feed efficiency (FE) of a beef animal is critical to producer profitability, but often varies considerably among individuals. Improvements in efficiency of beef production are necessary to sustain the cattle industry. The purpose of this research was to assess the repeatability of FE across growing and finishing phases of feedlot production as well across differing diet types. Additionally, we sought to better understand the contributions of diet digestibility to the FE phenotype of cattle.

## Experimental design and methodology

Animal use and methods are extensively described by Russell et al. (2016a). Briefly, this study was conducted over 5 years and utilized 985 crossbred steers (464 ± 32 kg initial BW) fed in 6 replicated groups. Steers were fed at the University of Missouri (MU) for the growing phase and at Iowa State University (ISU) for the finishing phase. Steers were received at MU for a minimum of 21 d prior to initiation of the growing phase portion of the trial. Steers were stratified by BW across growing phase diets including: a whole shell corn-based diet (G-Corn; 528 steers in total; Table 1) or a roughage-based diet (G-Rough; 457 steers; Table 2). Steers were housed in pens with GrowSafe equipped bunks and fed to ad libitum intake. Intermediate BW were recorded every 14 to 28 d and at the conclusion of the growing phase, which ranged in length from 69 to 89 d across the 6 groups. Residual feed intake (RFI) was calculated for steers within growing phase diet as suggested by Basarab et al. (2003) and all steers where shipped to ISU for finishing. At ISU steers were assigned to finishing pens (5 to 6 steers per pen) by growing phase diet and RFI ranking (upper, middle, or lower one-third of the group). Steers received diets nutritionally similar to their growing phase diets after arrival at ISU and were then transitioned to finishing diets that included: a dry rolled corn based diet (F-Corn; Table 3) or a byproduct-based diet (F-Byp). Steers received finishing diets until cattle were visually appraised to have 0.5 in of backfat, and were harvested at Tyson Fresh Meats (Denison, IA). All steers received ractopamine hydrochloride at a rate of 200 mg/hd per d for 27-32 d prior to harvest.

Following completion of the sixth and final group, data from all 985 steers (168 ISU finishing pens total) were collectively assessed. Average growing phase G:F was calculated for each set of steers (5 to 6 head) assigned to a finishing phase pen, and growing phase initial BW was used as a covariate in analysis with the Mixed procedure of SAS to calculate an adjusted growing phase G:F for a pen of cattle. Pens were then classified as highly (HFE; > 0.5 SD from the G:F mean; most efficient cattle), mid (MFE; ± 0.5 SD from the G:F mean), or lowly (LFE; < 0.5 SD from the G:F mean; least efficient cattle) feed efficient. Descriptive statistics about the pens of steers classified in these groupings are shown in Table 4. Data were analyzed using Proc Mixed of SAS, with finishing phase pen as the experimental unit and the model included the fixed effects of growing phase diet, growing phase feed efficiency classification, finishing phase diet and the interactions. Group (1 through 6) was included as a fixed effect as well. Finishing phase starting BW was used as a covariate in the model for finishing phase final BW, DMI, G:F, and HCW.

In groups 4 and 5 a subset of steers were utilized to assess the impact of FE phenotype on diet digestibility (methods described by Russell et al., 2016b). Upon arrival at ISU, following completion of the MU growing phase RFI determination, the 12 greatest and 12 least feed efficient steers from each of the two growing phase diets were selected from group 4 (n = 48, 509 ± 7 kg) and group 5 (n = 48, 467 ± 7 kg). Steers were housed in pens of 6 head, in pens equipped with GrowSafe bunks. Steers received diets nutritionally similar to their growing diets for 15 d, during which time titanium dioxide was included in the diets at an average of 10 g per head daily as an indigestible marker to estimate fecal output. Grab samples of feces were collected prior to feeding on d 14 and 15, and samples of total mixed rations were collected twice during the receiving period. Steers were then transitioned to finishing diets over a period of 18 d and finishing period diet digestibility was assessed by repeating the titanium dioxide feeding protocol immediately prior to addition of ractopamine hydrochloride, with fecal collections occurring on d 28, 29 (group 4) or d 68, 69 (group 5). Feces and diets were analyzed for DM, organic matter, neutral detergent fiber, acid detergent fiber, N, fat, and starch.

Data for the two groups (96 steers in total) were pooled, and steers were ranked by their growing phase G:F to be classified as the 24 greatest (HFE) or 24 least (LFE) feed efficient steers from each growing phase diet. Digestibility data were analyzed using Proc Mixed of SAS, with the receiving period model including the fixed effects of growing phase diet and growing phase FE classification and the interaction. Finishing period data were analyzed with the fixed effects of growing phase diet, growing phase FE classification, finishing phase diet and the interactions. Group (4 or 5) was included in the model as a fixed effect for both phases.

**Repeatability of feed efficiency across feeding phases and different diet types**

The greatest challenge facing beef producers seeking to measure FE is the ability to measure individual intakes. Measuring intakes in the feedlot requires substantial infrastructure, making intake measurements difficult and expensive (Arthur and Herd, 2008). Thus, measuring FE for a limited period would be beneficial if FE is repeatable over multiple feeding phases or can be predicted using one FE evaluation period. In the present study there were no growing phase diet × FE classification × finishing phase diet effects on finishing phase growth or carcass traits (Table 5).

Feed efficiency classification impacted marbling score of carcasses, where marbling score was lesser in the HFE steers (417 ± 5.6) than the MFE (433 ± 4.3) and LFE (439 ± 5.1) steers, while marbling score did not differ between MFE and LFE steers. There was no affect of the growing phase diet × finishing phase diet interaction or the growing phase diet × FE classification interaction on finishing phase G:F. However, finishing phase feed efficiency was impacted by growing phase FE classification (Fig. 1), where cattle classified as highly efficient in the growing phase had the best G:F in the finishing period and mid and lowly feed efficient cattle were similarly mid and least feed efficient in the finishing period. Table 6 shows the percent of pens of steers that remained in the same FE classification across both growing and finishing phases, moved one classification (i.e. low to mid, mid to high, etc), or moved two classifications (i.e. low to high or high to low). In general the trends are similar across diet combinations, though it appears cattle classified by FE while grown on roughage displayed more movement across classifications than cattle grown on corn, likely because of the similar nutritional profile between the G-Corn and finishing diets. Assessment of the correlation between adjusted growing phase G:F and finishing phase G:F amongst the differing diet combinations is shown in Table 6. The relationship was positive across all diet combinations and was significant for three of the four combinations, being strongest within cattle grown on corn, likely due to the similar nutritive profile between G-Corn and the finishing diets. The relationship was weakest within cattle grown on roughage and finished on byproduct-based diets but still reflects a positive correlation. The most variability in repeatability of FE across growing and finishing phases appears to be within steers fed fibrous diets and more work is needed to better understand the implication of NDF content and quality on FE determination.

Others have also examined the repeatability of FE over multiple feeding phases. Over three years, Durunna et al. (2011) collected growth and intake data on 490 crossbred steers during two consecutive feeding phases (growing and finishing). Within each year, steers either received the growing phase diet (74% oats, 20% grass hay) in both phases, the finishing phase diet (56.7% barley, 28.3% oats) in both phases or switched from the growing to finishing phase diet across the two periods (Durunna et al., 2011). Steers were classified as low, medium, or highly feed efficient using a 0.5 SD cutoff around the mean for G:F based on first period performance (Durunna et al., 2011). In the feed swap group, 61.6% switched G:F classification; however, similar classification changes were also observed in the all growing phase diet-fed group (G:F: 53.5% change) and the all finishing phase diet-fed group (G:F: 59.1% change; Durunna et al., 2011). Despite a seemingly large movement across classifications, Durunna et al. (2011) reported a far smaller proportion of the total feeding groups that actually moved two classifications (i.e. the low to high, or high to low FE classification; feed swap: 13.3% G:F; growing diet-fed: 11.2% G:F; finishing diet-fed: 11.2% G:F).

An interesting observation from the present study is that there was no interaction between MU growing diets and finishing period G:F, feed efficiency was achieved in different ways between cattle fed the two growing diets. Among those grown on corn HFE and MFE cattle ate less DM during the finishing period than those classified as LFE, while daily rates of gain were similar among the classification groupings. However, among steers grown on roughage, HFE and MFE steers had greater daily rates of gain than LFE steers while consuming similar amounts of DM across all three groupings. Differences in diet digestibility may help explain differences among individuals in feed efficiency, depending on the nutrient profile of the diet.

**Diet digestibility in beef cattle identified as phenotypic extremes for feed efficiency**

Table 7 shows descriptive statistics regarding steers utilized in diet digestibility assessments. Receiving phase diets were nutritionally similar to growing phase diets and diet digestibility data are shown in Table 8. Minimal differences between cattle grown on corn and classified as LFE and HFE were observed in digestibility of DM, organic matter, NDF, ADF, CP or starch. However, within steers grown on roughage-based diets, HFE steers excelled at fiber digestion over LFE steers, suggesting ability to digest fibrous diets more completely may have contributed to classification of these steers as highly feed efficient. Diet selectivity and eating behavior was not assessed in these trials and these factors may play important roles in identification of cattle as highly feed efficient on fibrous diets. There were no effects of growing phase FE classification on finishing phase diet digestibility (data not shown).

There was a positive correlation for DM digestibility between feeding phases when steers were grown and finished on similar diets, specifically the roughage-grown byproduct-finished steers and the corn-grown corn-finished steers (Table 9). Although there were no differences in DM digestibility due to FE classification, it does appear that digestibility measured during one feeding phase may help predict digestive capacity during a subsequent phase if similar diet types are fed. Interestingly, fiber digestibility appeared to contribute to FE variation while starch digestibility did not, indicating that there may be more opportunity for improving FE via selection or management for better fiber utilization. Feed efficiency classification effects were most pronounced for growing phase fiber digestibility advantages in the roughage-grown HFE steers. More work is needed to understand the mechanisms by which cattle make most efficient use of fibrous diets.

**Summary**

Completion of five years of work regarding repeatability of feed efficiency of cattle across growing and finishing phases and different diet types (corn or roughage) has increased our knowledge of feed efficiency. Steers classified as highly feed efficient (HFE) based on growing phase G:F maintained greater G:F in the finishing phase, a relationship that was also congruent for mid (MFE) and low (LFE) feed efficient steers. Thus, growing phase FE appeared to be a reasonable predictor of finishing phase FE. Perhaps the most interesting revelation was that although finishing phase G:F was not directly affected by growing or finishing phase diets, an evaluation of other growth traits revealed differences in how G:F differences resulted from underlying sources of variation. Among steers grown on roughage, finishing phase ADG differed between FE classifications yet DMI was unaffected by FE classification. Dissimilarly, among the corn-grown steers there were no differences detected in finishing phase ADG between FE classifications but DMI differed between classifications. Thus, it appeared that ADG differences were responsible for finishing phase G:F variation among roughage-grown steers whereas differences in finishing phase G:F among the corn-grown steers resulted from differences in DMI. Though growth performance was affected by growing phase diet and FE classification, carcass differences were limited. There were limited differences among corn-grown steers or corn-finished steers; hence, diet-driven differences were largely isolated to steers fed the high fiber diets.

Examining the relationship between FE across multiple growth phases and diet types is important for determining means by which to select and manage cattle based on FE phenotype.

Ultimately, FE was repeatable across feeding phases but growing phase FE may be a better predictor of subsequent FE when diet types between feeding phases are similar. Though starch digestibility had no relationship with FE, fiber digestibility contributes to FE variation between individuals. Future research should evaluate cattle performance using multiple growing and finishing phase diet combinations but may consider particularly focusing on high fiber diets as roughage-grown steers were the predominant source of variation in the present studies. Understanding the digestive differences between highly and lowly feed efficient steers may be best accomplished by exploring differences in microbial populations/activities.

The ultimate goal of this research is to advance improvement in the beef industry through development of tools and management strategies for producers. Suggested application of our research findings might eventually include testing cattle at weaning to determine their genetic predisposition to be superior fiber digesters, sending those cattle to backgrounding systems to make the most efficient use of low quality, affordable, fibrous feedstuffs while sending the poorer fiber digesters directly to the feedlot to become calf feds. More work is needed before we reach this goal, but ultimately, efficiency of beef cattle production and overall sustainability of the industry can be improved if we understand both the genetic potential and nutritional management required to optimize the cattle feed efficiency.

**Literature Cited**

Arthur, P. F., and R. M. Herd. 2008. Residual feed intake in beef cattle. Revista Brasileira de Zootecnia. 37: 269-279.

Durunna, O. N., F. D. N. Mujibi, L. Goonewardene, E. K. Okine, J. A. Basarab, Z. Wang, and S. S. Moore. 2011. Feed efficiency differences and reranking in beef steers fed grower and finisher diets. J. Anim. Sci. 89: 158-167. doi: 10.2527/jas.2009-2514.

Russell, J. R., E. L. Lundy, N. O. Minton, W. J. Sexten, M. S. Kerley, S. L. Hansen, and National Program for Genetic Improvement of Feed Efficiency in Beef Cattle. 2016a. Influence of growing phase feed efficiency classification on finishing phase growth performance and carcass characteristics of beef steers fed different diet types. J. Anim. Sci. 94:1610–1619. doi: 10.2527/jas.2015-0267

Russell, J. R., N. O. Minton, W. J. Sexten, M. S. Kerley, S. L. Hansen, and National Program for Genetic Improvement of Feed Efficiency in Beef Cattle. 2016b. Influence of feed efficiency classification on diet digestibility and growth performance of beef steers. J. Anim. Sci. (in press). doi:10.2527/jas.2015-9949.

Table 1. Composition and analysis of growing phase whole shell corn-based diets (G-Corn) fed to steers (From Russell et al., 2016a)

| | Group[1] | | | |
|---|---|---|---|---|
| Ingredient, % DM | 1, 2, 3 | 4 | 5 | 6 |
| Whole shell corn | 78.59 | 70.92 | 65.10 | 64.26 |
| Dried distillers grains | 9.72 | 17.00 | 24.50 | 26.07 |
| Soyplus[2] | 6.25 | 6.38 | 4.51 | 4.96 |
| Wheat middlings | 2.65 | 2.00 | - | - |
| Porcine blood meal | - | 1.30 | 3.50 | 2.52 |
| Limestone | 1.50 | 1.40 | 1.21 | 1.09 |
| Urea | 0.39 | 0.60 | 0.47 | 0.19 |
| Choice white grease | 0.20 | 0.12 | 0.10 | 0.19 |
| Salt | 0.17 | 0.04 | 0.13 | 0.22 |
| Vitamin premix[3] | 0.17 | 0.16 | 0.25 | 0.23 |
| Trace mineral premix[4] | 0.17 | 0.07 | 0.09 | - |
| Potassium chloride | 0.17 | - | - | - |
| Pellet binder | - | - | 0.13 | 0.19 |
| Rumensin 90[5] | 0.01 | 0.01 | 0.01 | 0.01 |
| Nutritional analysis[6] | | | | |
| DM, % as-fed basis | 90.7 | 90.3 | 88.3 | 85.1 |
| NDF, % DM | 17.8 | 20.2 | 21.1 | 26.4 |
| ADF, % DM | 4.4 | 5.0 | 4.9 | 6.5 |
| CP, % DM | 17.2 | 17.9 | 23.1 | 20.5 |

[1] Steers fed in 6 separate, replicated groups.
[2] Soyplus (West Central Cooperative, Ralston, IA).
[3] Vitamin premix fulfills 2,200 IU vitamin A, 275 IU vitamin D, 100 IU vitamin E per kg of diet.
[4] Trace mineral premix fulfills 10 mg Cu, 50 mg Fe, 20 mg Mn, 30 mg Zn, 0.1 mg Co, 0.1 mg Se, 0.5 mg I per kg diet.
[5] Provided Monensin at 150 mg$\cdot$steer$^{-1}\cdot$d$^{-1}$, Elanco Animal Health, Indianapolis, IN.
[6] Determined from analysis of total mixed ration samples collected weekly and composited by month.

Table 2. Composition and analysis of growing phase forage and soybean hull-based diets (G-Rough) fed to steers (From Russell et al., 2016a)

| | Group[1] | | | |
|---|---|---|---|---|
| Ingredient, % DM | 1, 3 | 4 | 5 | 6 |
| Soybean hull pellets | 40.81 | 36.57 | 38.16 | 36.84 |
| Alfalfa/grass baleage | 34.21 | - | - | - |
| Corn Silage | - | 36.00 | - | - |
| Rye baleage | - | - | 32.49 | - |
| Sudan baleage | - | - | - | 36.25 |
| Dried distillers grains | 15.13 | 15.00 | 22.24 | 22.70 |
| Soyplus[2] | - | 5.50 | 4.05 | 1.75 |
| Porcine blood meal | - | 0.80 | 2.02 | 1.65 |
| Ground corn | 8.62 | 5.00 | - | - |
| Limestone | 0.57 | 0.70 | 0.61 | 0.35 |
| Salt | 0.25 | 0.07 | 0.11 | 0.18 |
| Vitamin premix[3] | 0.20 | 0.20 | 0.20 | 0.18 |
| Trace mineral premix[4] | 0.20 | 0.13 | 0.07 | 0.07 |
| MFP[5] | - | 0.03 | 0.05 | 0.03 |
| Rumensin 90[6] | 0.01 | 0.01 | 0.01 | 0.01 |
| Nutritional analysis[7] | | | | |
| DM, % as-fed basis | 79.4 | 68.9 | 68.3 | 66.8 |
| NDF, % DM | 50.1 | 46.9 | 52.3 | 57.5 |
| ADF, % DM | 32.5 | 26.5 | 29.0 | 31.5 |
| CP, % DM | 17.2 | 16.0 | 22.3 | 20.8 |

[1] Steers fed in 6 separate, replicated groups; forage and soybean hull-based diet was not fed during group 2.
[2] Soyplus (West Central Cooperative, Ralston, IA).
[3] Vitamin premix fulfills 2,200 IU vitamin A, 275 IU vitamin D, 100 IU vitamin E per kg of diet.
[4] Trace mineral premix fulfills 10 mg Cu, 50 mg Fe, 20 mg Mn, 30 mg Zn, 0.1 mg Co, 0.1 mg Se, 0.5 mg I per kg diet.
[5] DL-methionine hydroxy analogue calcium (84 % methionine, Novus International, Saint Charles, MO).
[6] Provided Monensin at 150 mg$\cdot$steer$^{-1}\cdot$d$^{-1}$, Elanco Animal Health, Indianapolis, IN.
[7] Determined from analysis of total mixed ration samples collected weekly and composited by month.

Table 3. Composition and analysis of finishing phase diets fed to steers[1] (From Russell et al., 2016a)

| | Finishing phase diets[2] | |
|---|---|---|
| Ingredient, % DM | F-Corn | F-Byp |
| Cracked corn | 75 | 30 |
| Dried distillers grains | 14.99 | 39.99 |
| Soybean hull pellets | - | 20 |
| Bromegrass hay | 8 | 8 |
| Limestone | 1.54 | 1.54 |
| Salt | 0.31 | 0.31 |
| Vitamin A premix[3] | 0.11 | 0.11 |
| Trace mineral premix[4] | 0.035 | 0.035 |
| Rumensin 90[5] | 0.013 | 0.013 |
| Nutritional analysis[6] | | |
| DM, % as-fed basis | 84.5 | 84.1 |
| NDF, % DM | 24.4 | 42.7 |
| ADF, % DM | 8.0 | 18.7 |
| CP, % DM | 11.2 | 18.4 |

[1] Steers were fed in 6 separate, replicated groups; ingredient composition of finishing phase diets was consistent across all 6 groups.
[2] Finishing phase diets: F-Corn = cracked corn-based; F-Byp = dried distillers grains and soybean hull-based.
[3] Vitamin A premix contained 4,400,000 IU/kg.
[4] Provided per kilogram of diet (from inorganic sources): 30 mg Zn, 20 mg Mn, 0.5 mg I, 0.1 mg Se, 10 mg Cu, 0.1 mg Co.
[5] Provided Monensin at 200 mg$\cdot$steer$^{-1}\cdot$d$^{-1}$, Elanco Animal Health, Indianapolis, IN.
[6] Determined from analysis of total mixed ration samples collected weekly and composited by month.

Table 4. Descriptive statistics of growing phase feed efficiency classifications calculated for finishing phase pens across all groups (From Russell et al., 2016a)

| | Growing phase diets[1] | | | | | |
|---|---|---|---|---|---|---|
| | G-Corn | | | G-Rough | | |
| | Growing phase feed efficiency classifications[2] | | | | | |
| | HFE | MFE | LFE | HFE | MFE | LFE |
| Pens (n) | 24 | 41 | 25 | 20 | 34 | 24 |
| G:F[3] | | | | | | |
| Average | 0.258 | 0.218 | 0.180 | 0.228 | 0.196 | 0.169 |
| Minimum | 0.235 | 0.203 | 0.141 | 0.211 | 0.185 | 0.144 |
| Maximum | 0.298 | 0.233 | 0.202 | 0.262 | 0.208 | 0.183 |

[1] Growing phase diets: G-Corn = whole shell corn-based; G-Rough = forage and soybean hull-based.

[2] Growing phase feed efficiency classifications: HFE = highly feed efficient (> 0.5 SD from the G:F mean); MFE = mid feed efficiency (± 0.5 SD from the G:F mean); LFE = lowly feed efficient (< 0.5 SD from the G:F mean).

[3] Growing phase G:F for each finishing phase pen calculated using individual BW and DMI data for each steer housed in a finishing phase pen, and utilizing growing phase initial BW as a covariate in the MIXED procedure of SAS 9.3 (SAS Institute Inc., Cary, NC).

Table 5. Effect of growing phase diet and feed efficiency classification on finishing phase growth performance and carcass traits (From Russell et al., 2016a)

| | Growing phase diets[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | G-Corn | | | G-Rough | | | | |
| | Growing phase feed efficiency classifications[2] | | | | | | | |
| | LFE | MFE | HFE | LFE | MFE | HFE | SEM | *P*-value[3,4] |
| Live performance | | | | | | | | |
| Initial BW[5], kg | 448 | 457 | 459 | 460 | 462 | 475 | - | - |
| Final BW [6, 7], kg | 615[ab] | 609[bc] | 605[c] | 605[c] | 612[ab] | 618[a] | 2.6 | 0.001 |
| ADG, kg/d | 1.85[ab] | 1.79[bc] | 1.78[bc] | 1.72[c] | 1.82[ab] | 1.87[a] | 0.029 | 0.005 |
| DMI[7], kg/d | 11.3[a] | 10.7[bc] | 10.6[c] | 11.0[ab] | 11.1[a] | 11.2[a] | 0.12 | 0.002 |
| Carcass traits | | | | | | | | |
| HCW[7], kg | 389[a] | 386[a] | 381[b] | 385[ab] | 387[a] | 390[a] | 1.9 | 0.003 |
| REA[8], $cm^2$ | 86.6[c] | 89.6[b] | 87.9[bc] | 87.9[bc] | 89.1[b] | 91.7[a] | 0.78 | 0.01 |

[a, b, c] Least squares means in a row without common superscript differ ($P < 0.05$).

[1] Growing phase diets: G-Corn = whole shell corn-based; G-Rough = forage and soybean hull-based.

[2] Growing phase feed efficiency classifications: HFE = highly feed efficient (> 0.5 SD from the G:F mean); MFE = mid feed efficiency (± 0.5 SD from the G:F mean); LFE = lowly feed efficient (< 0.5 SD from the G:F mean).

[3] Interaction effect of growing phase diet and feed efficiency classification.

[4] Growing phase diet × feed efficiency classification interaction was not significant ($P \geq 0.14$) for G:F, dressing percent, backfat, KPH, yield grade, or marbling score; Three way interaction between growing phase diet, finishing phase diet, and growing phase feed efficiency classification was not significant ($P > 0.2$).

[5] Initial BW pencil shrunk 4 %.

[6] Final BW, pencil shrunk 4 %.

[7] Initial BW applied as a covariate.

[8] Ribeye area.

Table 6. Effect of growing phase and finishing phase diets on feed efficiency classification shifts by steers and the correlation between growing phase and finishing phase G:F.

| | | Percent of pens changing feed efficiency classifications from growing to finishing | | | Correlation of G:F between phases[1] |
|---|---|---|---|---|---|
| Item | Pens (n) | No change | One classification | Two classifications | r (*P*-value) |
| G-Corn | 90 | 51.1% | 41.1% | 7.8% | |
| F-corn | 45 | 48.9% | 40.0% | 11.1% | 0.47 (0.001) |
| F-Byp | 45 | 53.3% | 42.2% | 4.4% | 0.40 (0.007) |
| G-Rough | 78 | 41.0% | 42.3% | 16.7% | |
| F-Corn | 39 | 43.6% | 43.6% | 12.8% | 0.37 (0.02) |
| F-Byp | 39 | 38.5% | 41.0% | 20.5% | 0.29 (0.08) |
| Overall | 168 | 46.4% | 41.7% | 11.9% | |

[1]Pearson's correlation (r) and associated P-value for the relationship between adjusted growing phase G:F and finishing phase G:F.

Table 7. Descriptive statistics of growing phase growth performance for steers fed corn or roughage-based diets and classified as least or most feed efficient and utilized in diet digestibility assessments (Groups 4 and 5)[1] (From Russell et al., 2016b)

| | Diet[2] | | | |
|---|---|---|---|---|
| | G-Corn | | G-Rough | |
| | FE Classification[3] | | | |
| Item | LFE | HFE | LFE | HFE |
| Steers, n | 24 | 24 | 24 | 24 |
| Initial BW, kg | 308.9 | 279.0 | 309.1 | 282.3 |
| Final BW, kg | 432.6 | 415.8 | 439.7 | 428.7 |
| ADG, kg/d | 1.75 | 1.90 | 1.89 | 1.98 |
| DMI, kg | 9.72 | 7.14 | 10.28 | 8.87 |
| G:F | 0.181 | 0.269 | 0.186 | 0.228 |
| Minimum | 0.102 | 0.208 | 0.087 | 0.178 |
| Maximum | 0.198 | 0.315 | 0.176 | 0.302 |

[1] Pooled values from steers selected as most and least feed efficient from each of two diets fed in two separate groups (48 selected steers/group: 24 steers/diet, 12 steers/FE classification within diet).
[2] Growing phase diets: G-Corn = whole shell corn-based; G-Rough = forage and soybean hull-based.
[3] Growing phase feed efficiency classifications: LFE = least feed efficient, poorest G:F; HFE = most feed efficient, greatest G:F.

Table 8. Receiving phase digestibility as affected by growing phase feed efficiency classification and growing phase diets (From Russell et al., 2016b).

| | Growing phase diets[1] | | | | | *P*-values[3] | | |
|---|---|---|---|---|---|---|---|---|
| | G-Corn | | G-Rough | | | | | |
| | Growing phase feed efficiency classification[2] | | | | | | | |
| Item | LFE | HFE | LFE | HFE | SEM | Diet | FE | Diet×FE |
| Steers, n | 24 | 24 | 24 | 24 | - | - | - | - |
| DMI[4], kg | 8.9 | 8.6 | 10.0 | 10.0 | 0.37 | <0.001 | 0.71 | 0.79 |
| Digestibility, % | | | | | | | | |
| DM | 66.9 | 66.7 | 66.0 | 70.3 | 2.61 | 0.56 | 0.51 | 0.35 |
| OM | 68.9 | 68.4 | 68.2 | 72.8 | 2.58 | 0.42 | 0.51 | 0.31 |
| NDF | 58.1[b] | 57.1[b] | 59.2[b] | 73.0[a] | 3.03 | 0.003 | 0.08 | 0.01 |
| ADF | 46.8 | 46.6 | 60.2 | 69.4 | 3.84 | <0.001 | 0.34 | 0.20 |
| CP | 59.4 | 56.9 | 61.3 | 64.5 | 2.81 | 0.06 | 0.92 | 0.30 |
| Starch | 87.4 | 87.9 | 90.0 | 91.1 | 2.47 | 0.20 | 0.80 | 0.89 |

[a, b] Least squares means in a row without common superscript differ ($P < 0.05$).
[1] Growing phase diets: G-Corn = whole shell corn-based; G-Rough = forage and soybean hull-based.
[2] Growing phase feed efficiency classifications: LFE = least feed efficient, poorest G:F; HFE = most feed efficient, greatest G:F.
[3] *P*-values: Diet = main effect of growing phase diet; FE = main effect of growing phase feed efficiency classification; Diet×FE = interaction effect of growing phase diet and feed efficiency classification.
[4] Titanium dioxide supplementation period DMI, average of final 10 d prior to fecal collection.

Table 9. Dry matter digestibility correlations across growing and finishing phase diets.

| | | Dry matter digestibility[1] | |
|---|---|---|---|
| Growing phase diet[2] | Finishing phase diet[3] | Corr[4] | *P*-value |
| Corn | Corn | 0.49 | 0.02 |
| Corn | Byproduct | 0.25 | 0.3 |
| Roughage | Corn | 0.21 | 0.4 |
| Roughage | Byproduct | 0.68 | <0.001 |

[1] Dry matter digestibility correlations based on receiving phase and finishing phase diet digestibilities; receiving phase diets nutritionally similar to growing phase diets

[2] Growing phase diets: whole shell corn-based (Corn), forage and soybean hull-based (Roughage)

[3] Finishing phase diets: cracked corn-based (Corn), dried distillers grains and soybean hull-based (Byproduct)

[4] Corr: r, Pearson's correlation coefficient

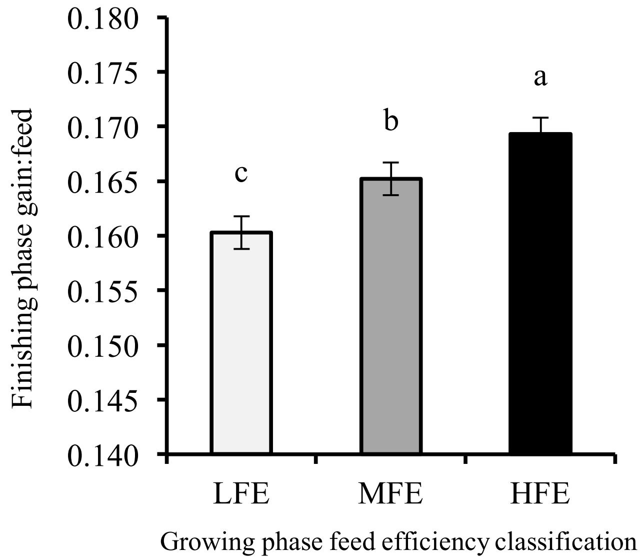


Figure 1. Finishing phase G:F in steers due to growing phase feed efficiency classification: HFE = highly feed efficient (> 0.5 SD from the growing phase G:F mean; n = 44 pens); MFE = mid feed efficiency (± 0.5 SD from the growing phase G:F mean; n = 75 pens); LFE = lowly feed efficient (< 0.5 SD from the growing phase G:F mean; n = 49 pens). Finishing phase initial BW applied as covariate. Values are means ± 0.0015, SEM. Means without common superscript differ ($P \leq 0.05$). From Russell et al. (2016a).