Title: Effects of rapid introduction and removal of high and low digestibility corn distillers dried grains from the diet, and dietary inclusion rates on growth performance and carcass characteristics of growing-finishing pigs – **NPB#09-044**

Investigators: Gerald Shurson, Adrienne Hilbrands, Lee Johnston, Sam Baidoo, Luiz Souza

Institution: University of Minnesota

Date Submitted: 7/28/2010

Industry Summary:

Due to inevitable price fluctuations of feed ingredients, pork producers and nutritionists are frequently seeking low cost feed ingredients capable of reducing overall feed expense without compromising pig performance and carcass quality. Dried distillers grains with solubles (DDGS) is commonly added to swine diets at minimal levels (10-20% inclusion) to decrease diet cost without diminishing pig performance. Currently, there is a tremendous economic advantage for feeding diets containing even greater levels (40 to 50%) of DDGS. No data have been published regarding the effects of feeding grower-finisher diets containing 40% or more DDGS on growth performance and carcass quality. Whitney et al. (2006) showed that growth performance and carcass characteristics of growing-finishing pigs are reduced when feeding diets containing 30% DDGS compared to diets containing 10 or 20% DDGS when diets were formulated on a total lysine basis. However, Xu et al. (2010) demonstrated that if diets are formulated on a digestible amino acid basis, DDGS may be added to growing-finishing swine diets at levels up to 30% without compromising growth performance and carcass quality.

The addition of DDGS to grower-finisher diets may only be economical intermittently throughout the grower-finisher phase depending on the market price and availability of DDGS. An earlier study conducted in our lab showed that the rapid inclusion and removal of 20% DDGS in diets for growing-finishing pigs does not affect pig performance or carcass characteristics; however, rapid inclusion and removal of 40% DDGS in diets may reduce daily feed intake and hot carcass weight (Hilbrands et al., 2008). These results provided the first evidence in the feasibility of capturing increased economic returns by rapidly introducing or removing DDGS (at or below 20% inclusion) from grower-finisher diets without compromising pig performance. However, dietary cost savings achieved from intermittently feeding a 40% DDGS based diet may be diminished due to the negative effects on performance and carcass characteristics associated with feeding a high level of DDGS.

Variability in nutrient content and digestibility among DDGS sources is well known. The physical appearance, chemical composition, and nutrient digestibility of DDGS can vary considerably depending on the source due to differences in processing and drying procedures (Cromwell et al., 1993). Modern ethanol plants generally produce DDGS that has greater concentrations of fat, lysine, and metabolizable energy (Spiehs et al., 2002) and improved digestibility of phosphorus (Whitney and Shurson, 2001) compared to values published in NRC (1998). Drescher et al. (2009) demonstrated that DDGS sources of low digestible crude protein and lysine may reduce pig performance, while higher digestible amino acid (AA) DDGS sources can support performance similar to a corn-soybean meal diet. Therefore, it appears that some of the inconsistent growth and carcass quality responses from feeding DDGS diets may be due to quality and AA digestibility differences in the DDGS sources used. The effects of switching diets that contain DDGS with low or high AA digestibility throughout the grower-finisher phase have not been documented. If it is possible to rapidly introduce and remove DDGS of differing AA digestibility without compromising pig performance, pork producers would be more likely to include DDGS at high levels in commercial grower-finisher swine diets. Therefore, our research group conducted an experiment to determine whether relatively high dietary levels of high digestible AA DDGS can be fed throughout the grower-finisher phase to achieve acceptable performance and carcass quality. Additionally, we sought to determine if intermittent inclusion of DDGS of different estimated AA digestibilities into diets can be achieved without affecting feed intake and carcass composition.

Three hundred twenty four pigs were housed in one of 36 pens and assigned to one of 6 dietary treatments. Dietary treatments consisted of: 1) a corn-soybean meal control (CON); 2) a corn-soybean meal diet containing 40% low AA digestibility DDGS (Lo); 3) a corn-soybean meal diet containing 40% high AA digestibility DDGS (Hi); 4) Lo and CON diets alternated throughout the trial (Lo-CON); 5) Hi and CON diets alternated throughout the trial (Hi-CON); and 6) a diet alternating between Hi and Lo (Hi-Lo). Feed switches between DDGS and non-DDGS based diets (Lo-CON and Hi-CON), as well as, between high AA digestibility DDGS diets and low AA digestibility diets (Hi-Lo) were implemented at phase changes. All phase changes were made on a pen basis when the average body weight (BW) of pigs in the pen was within 5 lb of the target weight for the phase change.

Final BW (Table 1) was affected by both the addition and AA digestibility of DDGS being fed with the final BW of pigs continuously consuming a DDGS based diet lower than those pigs consuming a corn-soybean meal diet. However, the continuous consumption of a low AA digestible DDGS diet resulted in lower growth rates than the continuous consumption of a high AA digestible DDGS diet when compared to corn-soybean meal fed pigs. Final BW was lower ($P < 0.05$) for Lo and Hi-Lo pigs when compared to CON pigs, while Hi pigs only tended to have lower ($P < 0.10$) final BW than CON pigs. Considering the differences in final BW, it is not surprising that gain followed the same trend. Average daily gains were reduced ($P < 0.05$) for Lo and Hi-Lo pigs when compared to the CON pigs while Hi pigs only tended to gain less ($P < 0.10$) than the CON pigs. Pigs continuously fed the Lo diet exhibited decreased ADFI in comparison to the CON pigs ($P < 0.10$). This suggests possible palatability issues with the low AA digestibility DDGS diet. Hasted et al. (2004) demonstrated that when given a choice pigs prefer a corn soybean-meal diet over a diet containing DDGS, and that as the level of DDGS in the diet increases ADFI decreases. Feed efficiency was not affected by treatments. Carcass traits were also negatively affected by the amount of DDGS fed as well as the AA digestibility of the DDGS being used (Table 2), with Lo and Hi-Lo pigs possessing smaller LMA than the CON pigs ($P < 0.05$). Hot carcass weights were also reduced ($P < 0.05$) for Lo and Hi-Lo pigs, while there was only a tendency for lighter ($P < 0.10$) HCW in Hi pigs when compared to CON pigs. Percentage carcass lean was not affected by dietary treatment whereas dressing percentage was lower for those pigs continuously consuming the Lo diet ($P < 0.05$). The intermittent consumption of DDGS did not affect growth performance or carcass quality with Lo-CON and Hi-CON pigs performing similarly to the CON pigs.

Results from this study suggest that pigs continuously fed a 40% low digestible AA DDGS based diet formulated on a Standardized Ileal Digestible (SID) AA basis, experience lower ADG, reduced ADFI, lighter HCW and smaller LMA than pigs continuously consuming a corn-soybean meal based diet. These results are consistent with previous findings (Whitney et al., 2006) where diets containing 30% DDGS resulted in reduced growth performance and carcass characteristics in growing-finishing pigs when compared to pigs consuming 0, 10 or 20% DDGS diets. This suggests that the estimated SID AA value and/or calculated ME content of the Lo diets was overestimated when formulating diets. It appears that the use of a high digestible AA DDGS source may be able to diminish the negative responses incurred in growth performance and carcass characteristics when feeding DDGS at a 40% level, suggesting that estimated SID AA values and ME content of the Hi diets was more accurate than values obtained for the Lo diet formulations. The periodic inclusion and removal of 40% DDGS from the diets of finishing pigs did not adversely affect growth performance or carcass characteristics regardless of the AA digestibility of DDGS being fed.

Table 1. Effects of DDGS quality and inclusion and removal on pig growth performance

Trait	CON	Lo-CON	Hi-CON	Lo	Hi	Hi-Lo	SEM
No. of Pens	6	6	6	6	6	6	
No. of Pigs	54	54	54	54	54	54	
Initial BW, lb	73.4	73.4	73.4	73.4	73.4	73.4	0.001
Final BW, lb	268.2[ab,x]	268.5[ab,x]	271.4[a]	255.8[c]	261.3[bc,y]	260.1[c]	5.202
ADG, lb	2.01[ab,x]	2.01[ab,x]	2.04[a]	1.88[c]	1.94[bc,y]	1.93[c]	0.001
ADFI, lb	5.89[x]	5.95[a]	6.08[a]	5.61[b,y]	5.88	5.87	0.009
F:G	2.93	2.96	2.98	2.98	3.05	3.05	0.002

[abc] Within a row means without a common superscript differ ($P < 0.05$).
[xy] Within a row means without a common superscript differ ($P < 0.10$).

Table 2. Effects of DDGS quality and inclusion and removal on pig carcass characteristics

Trait	CON	Lo-CON	Hi-CON	Lo	Hi	Hi-Lo	SEM
No. of Pens	6	6	6	6	6	6	
No. of Pigs	54	54	54	54	54	54	
Ultrasound BF, in	0.84[a]	0.78	0.81	0.75	0.71[b]	0.78	0.001
Ultrasound LMA, in^2	6.93[a]	6.92[a]	7.02[a]	6.26[b]	6.62[ab]	6.29[b]	0.015
Hot carcass wt, lbs[1]	206.0[a]	203.8[ab,x]	208.3[a]	192.5[c]	197.3[bc,y]	195.3[c]	4.722
Carcass lean, %[1]	51.8	52.1	52.1	51.3	52.3	50.8	0.326
Dressing %[1]	76.2[a]	75.8[ab]	76.0[ab,x]	74.7[c]	75.1[bc,y]	74.6[c]	0.076

[abc] Within a row means without a common superscript differ ($P < 0.05$).
[xy] Within a row means without a common superscript differ ($P < 0.10$).
[1] Observations = CON n =52, Lo-CON n=53, Hi-CON n=53, Lo n=51, Hi n= 52, Hi-Lo n=54.

Scientific Abstract:

Effects of rapid introduction and removal from the diet of high and low quality corn distillers dried grains, and dietary inclusion rates on growth performance and carcass characteristics of growing-finishing pigs. A.M. Hilbrands[1], L. J. Johnston[1], and G. C. Shurson[2], S.K. Baidoo[3], L.W.O. Souza[2], [1]*University of Minnesota, West Central Research and Outreach Center, Morris,* [2]*University of Minnesota, St. Paul,* [3]*University of Minnesota, Southern Research and Outreach Center, Waseca*

Dried distillers grains with solubles (DDGS) is a low cost feed ingredient that can often be added to swine diets in order to decrease overall feed expense. Little is known about the effects of feeding DDGS at high levels (at or above 40% inclusion) throughout the grow-finish phase in addition to whether predicted amino acid digestibility levels of DDGS sources affect pig growth performance and carcass characteristics. Three hundred twenty-four crossbred pigs (initial BW = 73.4 ± 6.62 lb) were used to determine the effects of feeding a 40% DDGS based diet continuously throughout the grow-finish phase, as well as the effect of DDGS AA digestibility when fed continuously or intermittently throughout the grow-finish phase, on growth performance and carcass traits. Pigs were blocked by initial BW, and pens within block were randomly assigned to 1 of 6 dietary treatments in a 4-phase feeding program (36 pens; 9pigs/pen). Dietary treatments consisted of: 1) a corn-soybean meal control (CON); 2) a corn-soybean meal diet containing 40% low AA digestibility DDGS (Lo); 3) a corn-soybean meal diet containing 40% high AA digestibility DDGS (Hi); 4) Lo and CON diets alternated throughout the trial (Lo-CON); 5) Hi and CON diets alternated throughout the trial (Hi-CON); and 6) a diet alternating between Hi and Lo (Hi-Lo). Final BW was lower ($P < 0.05$, Table 3) for Lo and Hi-Lo pigs when

compared to CON pigs, while Hi pigs only tended to have lower ($P < 0.10$) final BW than CON pigs. Considering the differences in final BW, it is not surprising that gain followed the same trend. Average daily gains were reduced ($P < 0.05$) for Lo and Hi-Lo pigs when compared to the CON pigs while Hi pigs only tended to gain less ($P < 0.10$) than the CON pigs. Pigs continuously fed the Lo diet exhibited decreased ADFI in comparison to the CON pigs ($P < 0.10$). Feed efficiency was not affected by treatments. Loin muscle area was smaller for the Lo and Hi-Lo pigs in comparison to the CON pigs ($P < 0.05$, Table 4). Hot carcass weights were also reduced ($P < 0.05$) for Lo and Hi-Lo pigs, while there was only a tendency for lighter ($P < 0.10$) HCW in Hi pigs when compared to CON pigs. Percentage carcass lean was not affected by dietary treatment where as dressing percentage was lower for the Lo and Hi-Lo pigs when compared to the CON pigs ($P < 0.05$). Results from this study suggest that pigs continuously fed a 40% DDGS based diet, regardless of the predicted digestible AA of the DDGS source, experience lower ADG, reduced ADFI, lighter HCW and smaller LMA than those pigs continuously or intermittently consuming a corn-soybean based diet. However, the periodic inclusion and removal of 40% DDGS from the diets of finishing pigs did not adversely affect growth performance or carcass characteristics.

Introduction:

Due to the inevitable price fluctuations of feed ingredients, pork producers and nutritionists are frequently seeking low cost feed ingredients capable of reducing overall feed expense without compromising pig performance and carcass quality. Dried distillers grains with solubles (DDGS) is commonly added to swine diets at minimal levels (10-20% inclusion) to decrease diet cost without diminishing pig performance. Currently, there is a tremendous economic advantage for feeding diets containing even greater levels (40 to 50%) of DDGS. No data have been published regarding the effects of feeding grower-finisher diets containing 40% or more DDGS on growth performance and carcass quality. Whitney et al. (2006) showed that growth performance and carcass characteristics of growing-finishing pigs are reduced when feeding diets containing 30% DDGS compared to diets containing 10 or 20% DDGS when diets were formulated on a total lysine basis. However, Xu et al. (2010) demonstrated that if diets are formulated on a digestible amino acid basis, DDGS may be added to growing-finishing swine diets at levels up to 30% without compromising growth performance and carcass quality.

The addition of DDGS to grower-finisher diets may only be economical intermittently throughout the grower-finisher phase depending on the market price and availability of DDGS. An earlier study conducted in our lab showed that the rapid inclusion and removal of 20% DDGS in diets for growing-finishing pigs does not affect pig performance or carcass characteristics; however, rapid inclusion and removal of 40% DDGS in diets may reduce daily feed intake and hot carcass weight (Hilbrands et al., 2008). These results provided the first evidence in the feasibility of capturing increased economic returns by rapidly introducing or removing DDGS (at or below 20% inclusion) from grower-finisher diets without compromising pig performance. However, dietary cost savings incurred from intermittently feeding a 40% DDGS based diet may be diminished due to the negative effects on performance and carcass characteristics associated with feeding a high level of DDGS.

Variability in nutrient content and digestibility among DDGS sources is well known. The physical appearance, chemical composition, and nutrient digestibility of DDGS can vary considerably depending on the source due to differences in processing and drying procedures (Cromwell et al., 1993). Modern ethanol plants generally produce DDGS that has greater concentrations of fat, lysine, and metabolizable energy (Spiehs et al., 2002) and improved digestibility of phosphorus (Whitney and Shurson, 2001) compared to values published in NRC (1998). Drescher et al. (2009) demonstrated that DDGS sources of low digestible crude protein and lysine may reduce pig performance, while higher digestible amino acid (AA) DDGS sources can support performance similar to a corn-soybean meal diet. Therefore, it appears that some of the inconsistent growth and carcass quality responses from feeding DDGS diets may be due to quality and AA digestibility differences in the DDGS sources used. The effects of switching diets that contain DDGS with low or high AA digestibility throughout the grower-finisher phase have not been documented. If it is possible to rapidly introduce and remove DDGS of differing AA digestibility without compromising pig performance, pork producers would be more likely to include DDGS at high levels in commercial grower-finisher swine diets.

Objectives:

To determine the effects of continuously feeding a 40% DDGS based diet on pig growth performance and carcass characteristics and to evaluate the accuracy of SID AA estimates of DDGS sources when fed continuously or intermittently throughout the growing-finishing phase.

Materials & Methods:

Animals and Facilities

The experimental protocol used in this study was approved by the University of Minnesota Institutional Animal Care and Use Committee. The experiment was conducted in the swine research unit at the University of Minnesota's West Central Research and Outreach Center in Morris, Minnesota. The experiment was conducted from November 18, 2009 through February 24, 2010. Pigs were Duroc sired terminal offspring of Genetically Advanced Pigs (Winnipeg, MB, CA, Yorkshire x Landrace) sows.

Three hundred twenty four, mixed-sex pigs (initial BW = 73.4 ± 6.6 lb) were weighed and blocked by initial body weight (6 pens/block, 9 pigs/pen). Sex ratio was kept similar among pens (5 barrows and 4 gilts or 4 barrows and 5 gilts). Pigs within a block were assigned randomly to one of 6 dietary treatments resulting in 6 pens per treatment. Each pen was then assigned randomly to one of 36 pens within an environmentally-controlled, grower-finisher barn with a target room temperature of 68˚F. Each pen (5.25 ft x 14.75 ft) was equipped with 2 nipple waterers, one 4-space self-feeder and totally-slatted floors. Pigs were allowed *ad libitum* access to feed and water throughout the trial.

Dietary Treatments

Corn-soybean meal and DDGS-containing diets were formulated on a Standardized Ileal Digestible (SID) amino acid basis using digestibility coefficients obtained from a previous study (Urriola et al., 2007). Two sources of DDGS were used for the experiment. A high digestible AA DDGS source was obtained from LincolnLand Agri-Energy, LLC (Palestine, IL) and a low digestible AA DDGS source was obtained from Center Ethanol Company, LLC (Sauget, IL). Each source of DDGS was purchased in a single lot. All diets met or exceeded NRC (1998) nutrient requirements for growing-finishing pigs gaining 350 g leangain/day. The three diets used during each phase (Table 1) consisted of a typical corn-soybean meal control (CON), a corn-soybean meal diet containing 40% low digestible AA DDGS (Lo), and a corn-soybean meal diet containing 40% high digestible AA DDGS (Hi). All pigs were consuming the CON diet prior to the beginning of the trial. Four samples of each diet (one sample from each of the 4 phases, 12 samples total) were randomly selected for laboratory analyses for nutrient composition (DM, CP, Ca, P, NDF, ADF, and Fat) and mycotoxin levels at a commercial plant (Minnesota Valley Testing Laboratories, Inc., New Ulm, MN). The six dietary treatments included: 1) a corn-soybean meal control (CON); 2) a corn-soybean meal diet containing 40% low amino acid digestibility DDGS fed continuously (Lo); 3) a corn-soybean meal diet containing 40% high amino acid digestibility DDGS fed continuously (Hi); 4) Lo and CON diets alternated throughout the trial (Lo-CON); 5) Hi and CON diets alternated throughout the trial (Hi-CON); and 6) a diet alternating between Hi and Lo (Hi-Lo). Feed switches between DDGS and non-DDGS based diets (Lo-CON and Hi-CON), as well as, between high AA digestibility DDGS diets and low AA digestibility diets (Hi-Lo) were implemented at phase changes. All phase changes were made on a pen basis when the average body weight of pigs in the pen was within 5 lb of the target weight for the phase change (Table 2). Phases were based on the following BW: 73 to 110 lb, 111 to 150 lb, 151 to 200 lb, and 201 lb to market.

Performance Measurements

Body weight of individual pigs was determined bi-weekly and used to calculate ADG. Pen feed disappearance was also measured on the same day that pigs were weighed in order to calculate bi-weekly average daily feed intake on a pen basis (ADFI). To better understand how diet switches affected ADFI, feed disappearance was also calculated on d 3 following a diet phase change. Body weight gain and pen feed disappearance were used to calculate feed efficiency.

Carcass Measurements

Pigs were harvested on a single date in a commercial abattoir (Hormel Foods Corp., Austin, MN) when the average final BW of all pigs was 264 lbs. Five days pre-slaughter, real-time ultrasound imaging (Aloka 500V SSD) by a trained and certified technician was used to collect loin muscle area (LMA) and 10^{th} rib back fat depth on all pigs (n = 324). Hot carcass weight (HCW) was collected at the abattoir and used with the ultrasound data and final BW to calculate dressing percentage and carcass lean percentage. Carcass lean percentage was calculated using the following formula: Carcass lean percentage = (((0.833 x sex of pig (barrow = 1, and gilt = 2)) – (16.498 x 10^{th} rib fat depth, inches) + (5.425 x 10^{th} rib LMA, in^2) + (0.291 x live wt., lbs.) – 0.534)/live weight) x 100)/0.74 (NPPC, 2000). A few pigs (n = 9, AVG BW = 215.0 lb) were too light for commercial harvest so HCW, dressing percent, and carcass lean percent were measured on 315 pigs.

Statistical Analysis

Data were analyzed in a randomized complete block design using the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC). The statistical model for overall performance and carcass characteristics included dietary treatment as a fixed effect and block as a random effect. Pen was the experimental unit.

Repeated measures analysis was used to determine the effects of dietary treatments on performance data collected across consecutive diet phases. Treatment and time were fixed effects, block was a random effect, and pen was the experimental unit in the model. Unstructured, first-order autoregressive, and first-order antedependence covariance structures were used to model the errors within experimental units across time. Akaike's Information Criterion (AIC) was used to determine the most appropriate covariance structure for each variable with the smallest AIC value indicating the best fit model.

The effect of dietary switches on ADFI was also analyzed using a repeated measures analysis. Days, phase, and sequence were included as fixed effects, block was a random effect and pen was the experimental unit. The covariance structure used was first-order antedependence.

All reported means are least square means. Means separation was accomplished by the PDIFF option of SAS with the Tukey-Kramer adjustment. Satterthwaite's procedure was used to approximate the denominator degrees of freedom. The significance level was set at $P < 0.05$, with $0.05 < P < 0.10$ indicating a trend.

Results:

Pigs began the trial on 11/18/2009 and were harvested on 02/24/2010 with 98 days on feed. Final BW was lower ($P < 0.05$, Table 3) for Lo and Hi-Lo pigs when compared to CON pigs, while Hi pigs only tended to have lower ($P < 0.10$) final BW than CON pigs. Considering the differences in final BW, it is not surprising then that gain followed the same trend. Average daily gains were reduced ($P < 0.05$) for Lo and Hi-Lo pigs when compared to the CON pigs while Hi pigs only tended to gain less ($P < 0.10$) than the CON pigs. Pigs continuously fed the Lo diet exhibited decreased ADFI in comparison to the CON pigs ($P < 0.10$). Feed efficiency was not affected by treatments. Loin muscle area was smaller for the Lo and Hi-Lo pigs in comparison to the CON pigs ($P < 0.05$, Table 4). Hot carcass weights were also reduced ($P < 0.05$) for Lo and Hi-Lo pigs, while there was only a tendency for lighter ($P < 0.10$) HCW in Hi pigs when compared to CON pigs. Percentage carcass lean was not affected by dietary treatment where as dressing percentage was lower for the Lo and Hi-Lo pigs when compared to the CON pigs ($P < 0.05$).

When analyzed over time, ADG (Figure 1) was reduced ($P < 0.05$) 4 times throughout the growing-finishing period for the Lo treatment pigs while ADFI (Figure 2) was reduced ($P < 0.05$) 3 times. Dietary switches also affected ADFI (Figure 3). Feed intakes averaged over the three days following a diet change were used to determine the effect of dietary switches on ADFI. There were 9 possible dietary switches throughout the study including: 1) CON followed by Lo (CL), 2) CON followed by Hi (CH), 3) Lo followed by Lo (LL), 4) Hi followed by Lo (HL), 5) Hi followed by Hi (HH), 6) CON followed by CON (CC), 7) Lo followed by Hi (LH), 8) Lo followed by CON (LC), and 9) Hi followed by CON (HC). These switches are independent of the treatments and were included for any time a pig switched from one diet to another regardless of treatment or time. As an example, CH represents anytime a pig switched from the CON diet to the Hi diet. Recalling that all pigs were consuming the CON diet prior to the trial start, CH would then include the switch from CON diet to Hi diet for the Hi, Hi-CON, and Hi-Lo treatments as the beginning of the trial as well as anytime throughout the trial that the Hi-CON pigs made the switch from the CON to the Hi diet. Conversely, HC represents any switch from Hi to CON which only would have occurred for the Hi-CON pigs. Because of the treatment design, there are unequal observations for each of the 9 possible dietary switches. This approach to analysis was used to try and understand the effects of an abrupt diet change on a pig's feed intake. Pigs experiencing a switch from a DDGS based diet to a CON diet (LC and HC) consumed more feed than those pigs continuously consuming the CON diet (CC, $P < 0.05$). Consequently, those pigs switching from a CON diet to a DDGS based diet (CL and CH) exhibited the greatest reductions ($P < 0.05$) in feed intake in comparison to CON pigs (CC). Feed efficiency (Figure 4) was not affected by treatment until the very last measurement day in which the Hi-CON pigs tended to be more efficient in utilizing feed than pigs assigned to Hi and Hi-Lo treatments.

Discussion:

Results from this study suggest that pigs continuously fed a 40% low digestible AA DDGS based diet formulated on a SID AA basis, experienced lower ADG, reduced ADFI, lighter HCW and smaller LMA than pigs continuously consuming a corn-soybean meal based diet. These results are consistent with previous findings (Whitney et al., 2006) where diets containing 30% DDGS resulted in reduced growth performance and carcass characteristics in growing-finishing pigs when compared to pigs consuming 0, 10 or 20% DDGS diets. This suggests that the estimated SID AA value and/or calculated ME content of the Lo diets was overestimated when formulating diets. It appears that the use of a highly digestible AA DDGS source may be able to partially diminish the negative responses incurred in growth performance and carcass characteristics when feeding DDGS at a 40% level. This suggests that estimated SID AA values and ME content of the Hi diets was more accurate than values obtained for the Lo diet formulations. However, even though the Hi treatment pigs tended to perform better than the Lo pigs in comparison to the CON pigs, those pigs continuously consuming a DDGS based diet, regardless of the AA digestibility of the DDGS used, still had lower ADG than the CON pigs. The additional reduction in ADFI with the Lo treatment pigs could possibly indicate that the poorer performance was partially due to reduced palatability of the Lo diets. Hasted et al. (2004) demonstrated that when given a choice pigs prefer a corn soybean-meal diet over a diet containing DDGS. Average daily feed intake was similar between the Hi and CON pigs indicating there were other factors responsible for the reduced growth rates. Most DDGS based diets are formulated in such a way that as the level of DDGS in the diet increases the CP level of the diet also increases (Stein and Shurson, 2009) to the point of being excessive. An excessive quantity of CP in the diet can increase plasma urea concentration and reduce ADFI and ADG in growing-finishing pigs (Goerl et al., 1995; Chen et al., 1999). Laboratory analyses of the diets reported numerically higher vomitoxin levels in the Hi and Lo diets than the CON diet, but levels were at or only slightly above the normal recommended allowance of 1 ppm. Therefore, the dietary concentration of vomitoxin contamination was not responsible for the reduced intakes of pigs consuming the Lo diet. Further strengthening this argument is the fact that vomitoxin levels were similar between the Lo and Hi diets but there were no differences in ADFI between the Hi and CON treatment pigs. Reductions in hot carcass weight and dressing percentage were also observed in those pigs continuously consuming a 40% DDGS based diet. These results are in agreement with previous findings where hot carcass weight and dressing percentage decreased as levels of DDGS increased (Linneen et al., 2008 and Feoli et al., 2007). Stein and Shurson (2008) noted a reduction in dressing percentage in 8 of the 18 experiments they reviewed where corn DDGS was fed to grower-finisher pigs. It has been theorized that the addition of high fiber ingredients to pig diets may result in decreased dressing percentage due to increased gut fill and increased intestinal mass (Kass et al., 1980). The periodic inclusion and removal of 40% DDGS from the diets of finishing pigs did not adversely affect overall growth performance or carcass characteristics regardless of the AA digestibility of the DDGS fed. Overall performance of the Lo-CON and Hi-CON pigs was similar to that of the CON pigs. These results do not agree with our previous research results of evaluating the effects of switching between control and DDGS diets (Hilbrands et al., 2008) where ADG and ADFI were reduced when pigs were intermittently consuming a 40% DDGS based diet. While pigs on the Lo-CON and Hi-CON treatments in the current study did experience decreases in ADFI when switched from a CON diet to a DDGS based diet intakes rebounded and actually increased to that above which the CON pigs were consuming when they switched back from the DDGS diet to the CON diet leading to a similar overall ADFI among the 3 treatments. It is interesting to note that there was a numerical reduction in ADFI when pigs switched from the Hi diet to the Lo diet while ADFI numerically increased when pigs were switched from the Lo diet to the Hi diet.

Results from this study suggest that pigs continuously fed a 40% DDGS based diet, regardless of the predicted digestible AA of the DDGS source, experience lower ADG, reduced ADFI, lighter HCW and smaller LMA than those pigs continuously or intermittently consuming a corn-soybean based diet. However, the periodic inclusion and removal of 40% DDGS from the diets of finishing pigs did not adversely affect growth performance or carcass characteristics.

Literature Cited

Chen, H. Y., A. J. Lewis, P. S. Miller, and J. T. Yen. 1999. The effect of excess protein on growth performance and protein metabolism of finishing barrows and gilts. J. Anim. Sci. 77:3238-3247.

Cromwell, G. L., K. L. Herkelman, and T. S. Stahly. 1993. Physical, chemical, and nutritional characteristics of distillers dried grains with solubles for chicks and pigs. J. Anim. Sci. 71: 679-686.

Drescher, A. J., S. K. Baidoo, L. J. Johnston, and G. C. Shurson. 2009 Effect of distiller's dried grains with solubles (DDGS) source on growth performance and carcass characteristics of growing-finishing pigs. J. Anim. Sci. 85 (E-Supp. 3): 80 (Abstr.).

Goerl, K. F., S. J. Eilert, R. W. Mandigo, H. Y. Chen, and P. S. Miller. 1995. Pork characteristics as affected by two populations of swine and six crude protein levels. J. Anim. Sci. 73:3621-3626.

Feoli, C., J. D. Hancock, C. Monge, T. L. Gugle, S. D. Carter, and N. A. Cole. 2007. Digestible energy content of corn- vs sorghum-based dried distillers grains with solubles and their effects on growth performance and carcass characteristics in finishing pigs. Page 131-136 in Kansas State Univ. Swine Day Report. Kansas State Univ. Manhattan.

Hastad, C. W., J. L. Nelssen, R. D. Goodband, M. D. Tokach, S. S. Dritz, J. M. DeRouchey, and N. Z. Frantz. 2005. Effect of dried distillers grains with solubles on feed preference in growing pigs. J. Anim. Sci. 83(Supp. 2): 73. (Abstr.)

Hilbrands, A. M., L. J. Johnston, G. C. Shurson, and I. Kim. 2009. Influence of rapid introduction and removal of dietary corn distillers dried grains with solubles (DDGS) on pig performance and carcass characteristics. J. Anim. Sci. 87(E-Suppl. 3):82.

Kass, M. L., P. J. val Soest, and W. G. Pond. 1980. Utilization of dietary fiber from alfalfa by growing swine. I. Apparent digestibility of diet componenets in specific segments of the gastrointestinal tract. J. Anim. Sci. 50:175-191.

Linneen, S. K., J. M. DeRouchey, S. S. Dritz, R. D. Goodband, M. D. Tokach and J. L. Nelssen. 2008. Effects of dried distillers grains with solubles on growing and finishing pig performance in a commercial environment. J. Anim. Sci. 86:1579-1587.

NPPC. 2000. Pork compostition and quality assessment procedures. National Pork Producers Council, Des Moines, IA.

NRC. National Research Council. 1998. Nutrient requirements for swine. 10^{th} ed. NRC, Washington, DC.

Spiehs, M. J., M. H. Whitney, and G. C. Shurson. 2002. Nutrient database for distiller's dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 80: 2639-2645.

Stein, H. H., and G. C. Shurson. 2009. BOARD INVITED REVIEW: The use and application of distillers dried grains with solubles (DDGS) in swine diets. J Anim. Sci. 87:1292-1303.

Urriola, P. E., D. Hoehler, C. Pedersen, H. H. Stein, L. J. Johnston, and G. C. Shurson. 2007. Determination of amino acid digestibility of corn, sorghum, and corn-sorghum blend of dried distiller's grains with solubles in growing pigs. J. Anim. Sci. 87: 2574-2580.

Whitney, M. H., and G. C. Shurson. 2001. Availability of phosphorus in distiller's dried grains with solubles for growing swine. J. Anim. Sci. 79 (Suppl. 1): 108. (Abstr.).

Whitney, M. H., G. C Shurson, L. J. Johnston, D. M. Wulf, and B. C. Shanks. 2006. Growth performance and carcass characteristics of grower-finisher pigs fed high-quality corn distillers grain with solubles originating form a modern Midwestern ethanol plant. J. Anim. Sci. 84: 3356-3363.

Xu, G., S. K. Baidoo, L. J. Johnston, D. Bibus, J. E. Cannon, and G. C. Shurson. 2010. Effects of feeding diets containing increasing content of corn distillers dried grains with solubles to grower-finisher pigs on growth performance, carcass composition and pork fat quality. J. Anim. Sci. 88: 1398-1410.

Table 1. Composition of experimental diets (as-fed basis)

Ingredient, % (As-fed basis)	Phase 1 (73 to 110 lb)			Phase 2 (111 to 150 lb)			Phase 3 (151 to 200 lb)			Phase 4 (201 lb to mkt)		
	CON[1]	Lo[1]	Hi[1]	CON	Lo	Hi	CON	Lo	Hi	CON	Lo	Hi
Corn	73.67	37.73	40.64	81.12	45.22	48.12	83.40	47.47	50.40	86.19	50.26	53.18
Soybean meal, 46% CP	23.85	20.10	17.27	16.51	12.72	9.90	14.31	10.56	7.71	11.50	7.75	4.90
Low digestible AA DDGS[2]	0.00	40.00	0.00	0.00	40.00	0.00	0.00	40.00	0.00	0.00	40.00	0.00
High digestible AA DDGS[2]	0.00	0.00	40.00	0.00	0.00	40.00	0.00	0.00	40.00	0.00	0.00	40.00
Limestone ($CaCO_3$)	0.94	1.29	1.39	0.83	1.18	1.28	0.74	1.09	1.19	0.76	1.12	1.22
Monocalcium phosphate	0.85	0.19	0.00	0.85	0.18	0.00	0.85	0.18	0.00	0.85	0.18	0.00
Salt (NaCl)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
VTM premix[3]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
L-Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Analyzed Composition												
Dry Matter, %	87.47	89.31	88.55	88.47	89.64	88.86	86.40	89.18	88.30	87.01	88.90	88.64
CP, %	17.30	23.40	23.00	10.90	20.80	19.40	11.40	19.10	17.70	13.80	18.10	17.60
Ca, %	0.58	0.70	0.46	0.56	0.51	0.17	0.49	0.60	0.58	0.58	0.55	0.66
P, %	0.48	0.63	0.53	0.44	0.47	0.34	0.46	0.59	0.54	0.58	0.52	0.53
NDF, %	8.30	17.50	16.10	9.40	17.10	15.10	10.00	17.90	16.60	9.40	15.50	17.00
ADF, %	2.58	6.79	5.98	1.96	7.28	6.62	2.70	6.53	5.61	1.81	6.85	5.35
Fat, %	2.49	5.29	4.56	2.69	5.36	4.89	2.64	5.27	5.04	2.86	5.38	4.90
Mycotoxins[4]:												
Fumonisin B1	< 0.2	0.73	0.79	< 0.2	0.82	0.82	< 0.2	0.78	0.82	< 0.2	0.79	0.78
Vomitoxin	0.32	1.06	1.26	0.30	1.04	1.14	0.36	1.10	1.07	0.31	1.11	1.08

[1] CON = corn-soybean meal control, Lo = diet containing 40% low digestible AA DDGS, Hi = diet containing 40% high digestible AA DDGS.

[2] Sources: High Digestible AA DDGS = LincolnLand Agri-Energy, LLC (Palestine, IL), Low Digestible AA DDGS = Center Ethanol Company, LLC (Sauget, IL).

[3] Premix supplied the following per kg of diet: vitamin A, 8,820 IU; vitamin D_3, 1,653.75 IU; vitamin E, 33.08 IU; vitamin K, 4.41 mg; riboflavin, 6.62 mg; niacin, 38.89 mg; pantothenic acid, 22.05 mg; vitamin B_{12}, 0.04 mg; iodine, 1.10 mg; selenium, 0.30 mg; zinc, 60.64 mg; iron, 36.38 mg; manganese, 12.13 mg; copper, 3.64 mg.

[4] Concentrations of Alfatoxin (B1, G1, B2, and G2), Fumonisin B2 and Zearalenone below detection limit of assay.

Table 2. Diet assignments for each experimental treatment

Treatment	Diet received			
	Phase 1 (73 to 110 lb)	Phase 2 (111 to 150 lb)	Phase 3 (151 to 200 lb)	Phase 4 (201 lb to market)
CON	CON	CON	CON	CON
Lo	Lo	Lo	Lo	Lo
Hi	Hi	Hi	Hi	Hi
Lo-Con	Lo	CON	Lo	CON
Hi-Con	Hi	CON	Hi	CON
Hi-Lo	Hi	Lo	Hi	Lo

Table 3. Effects of DDGS inclusion and removal and DDGS quality on pig growth performance

Trait	CON	Lo-CON	Hi-CON	Lo	Hi	Hi-Lo	SEM
No. of pens	6	6	6	6	6	6	
No. of pigs	54	54	54	54	54	54	
Initial BW, lb	73.4	73.4	73.4	73.4	73.4	73.4	0.001
Final BW, lb	268.2[ab,x]	268.5[ab,x]	271.4[a]	255.8[c]	261.3[bc,y]	260.1[c]	5.2
ADG, lb	2.01[ab,x]	2.01[ab,x]	2.04[a]	1.88[c]	1.94[bc,y]	1.93[c]	0.001
ADFI, lb	5.89[x]	5.95[a]	6.08[a]	5.61[b,y]	5.88	5.87	0.009
F:G	2.93	2.96	2.98	2.98	3.05	3.05	0.002

[abc] Within a row means without a common superscript differ ($P < 0.05$).
[xy] Within a row means without a common superscript differ ($P < 0.10$).

Table 4. Effects of DDGS inclusion and removal and DDGS quality on pig carcass characteristics

Trait	CON	Lo-CON	Hi-CON	Lo	Hi	Hi-Lo	SEM
No. of pens	6	6	6	6	6	6	
No. of pigs	54	54	54	54	54	54	
Ultrasound BF, in	0.84[a]	0.78	0.81	0.75	0.71[b]	0.78	0.001
Ultrasound LMA, in^2	6.93[a]	6.92[a]	7.02[a]	6.26[b]	6.62[ab]	6.29[b]	0.02
Hot carcass wt, lbs[1]	206.0[a]	203.8[ab,x]	208.3[a]	192.5[c]	197.3[bc,y]	195.3[c]	4.7
Carcass lean, %[1]	51.8	52.1	52.1	51.3	52.3	50.8	0.3
Dressing %[1]	76.2[a]	75.8[ab]	76.0[ab,x]	74.7[c]	75.1[bc,y]	74.6[c]	0.08

[abc] Within a row means without a common superscript differ ($P < 0.05$).
[xy] Within a row means without a common superscript differ ($P < 0.10$).
[1] Observations were 52, 53, 53, 51, 52, and 54 for CON, Lo-CON, Hi-CON, Lo, Hi, and Hi-Lo respectively.

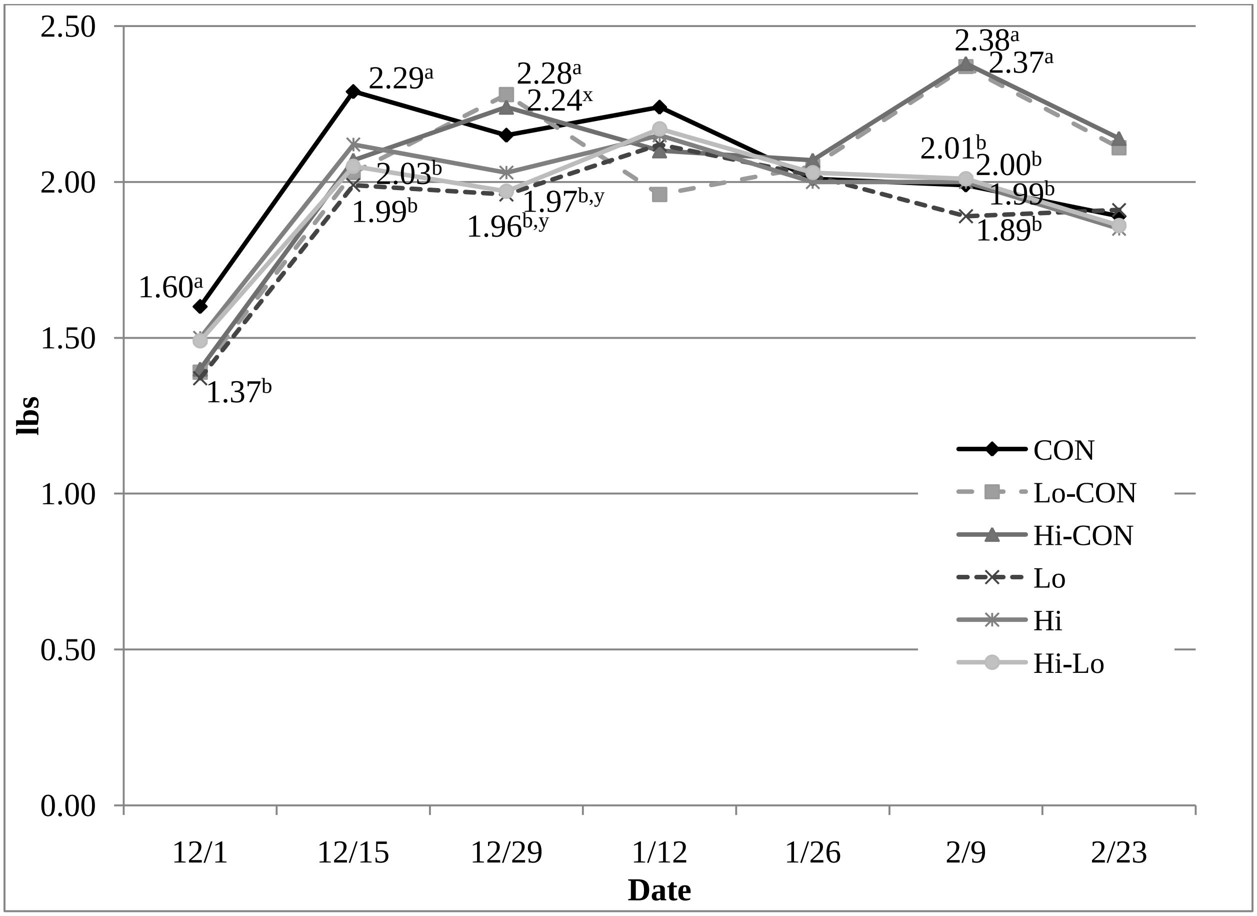

Figure 1. Effect of continuous and intermittent feeding of DDGS of varying AA digestibility on ADG.
[ab] Means within dates differ ($P < 0.05$). [xy] Means within dates differ ($P < 0.10$). Time: $P < 0.05$, Treatment*Time: $P < 0.05$.

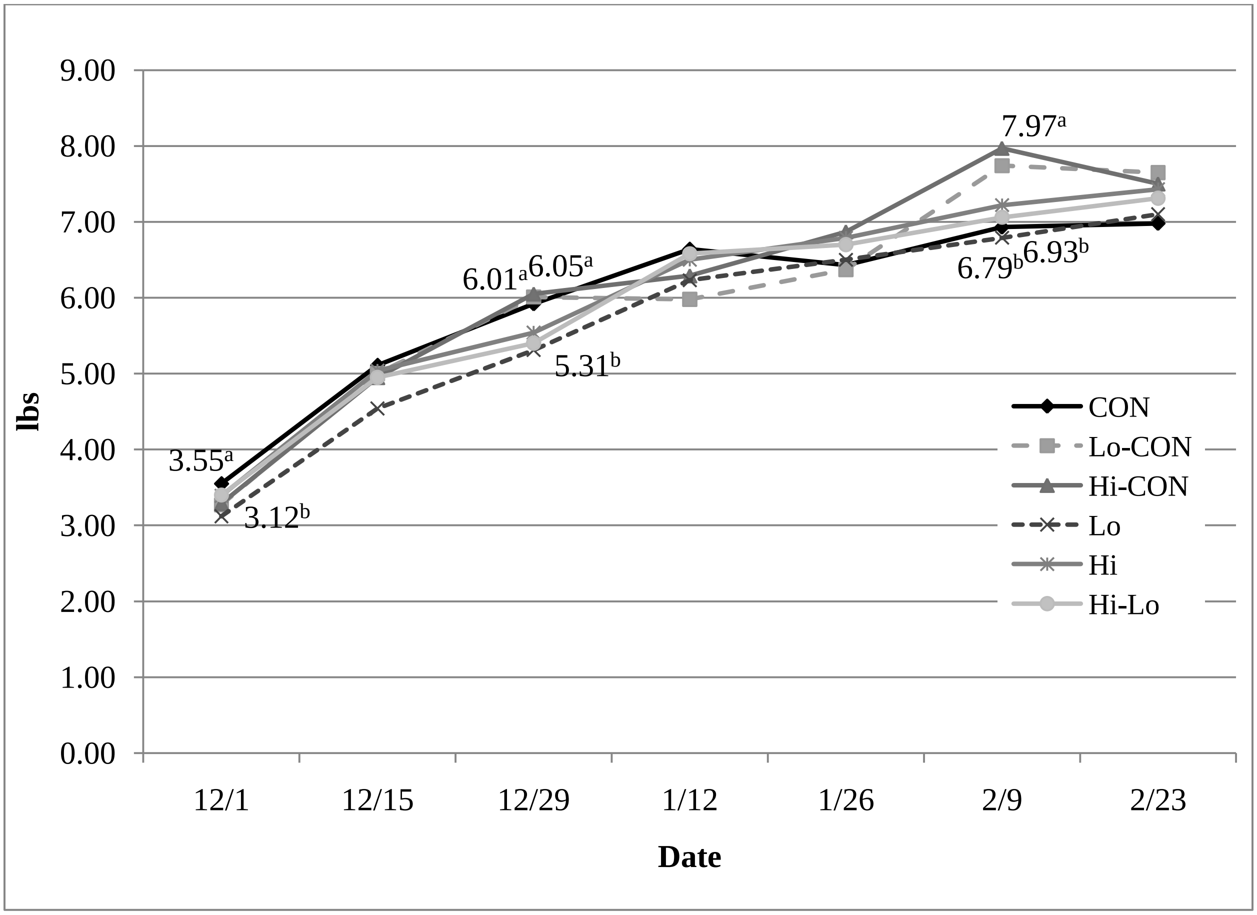

Figure 2. Effect of continuous and intermittent feeding of DDGS of varying AA digestibility on ADFI
[ab] Means within dates differ ($P < 0.05$). Time: $P < 0.05$, Treatment*Time: $P < 0.05$.

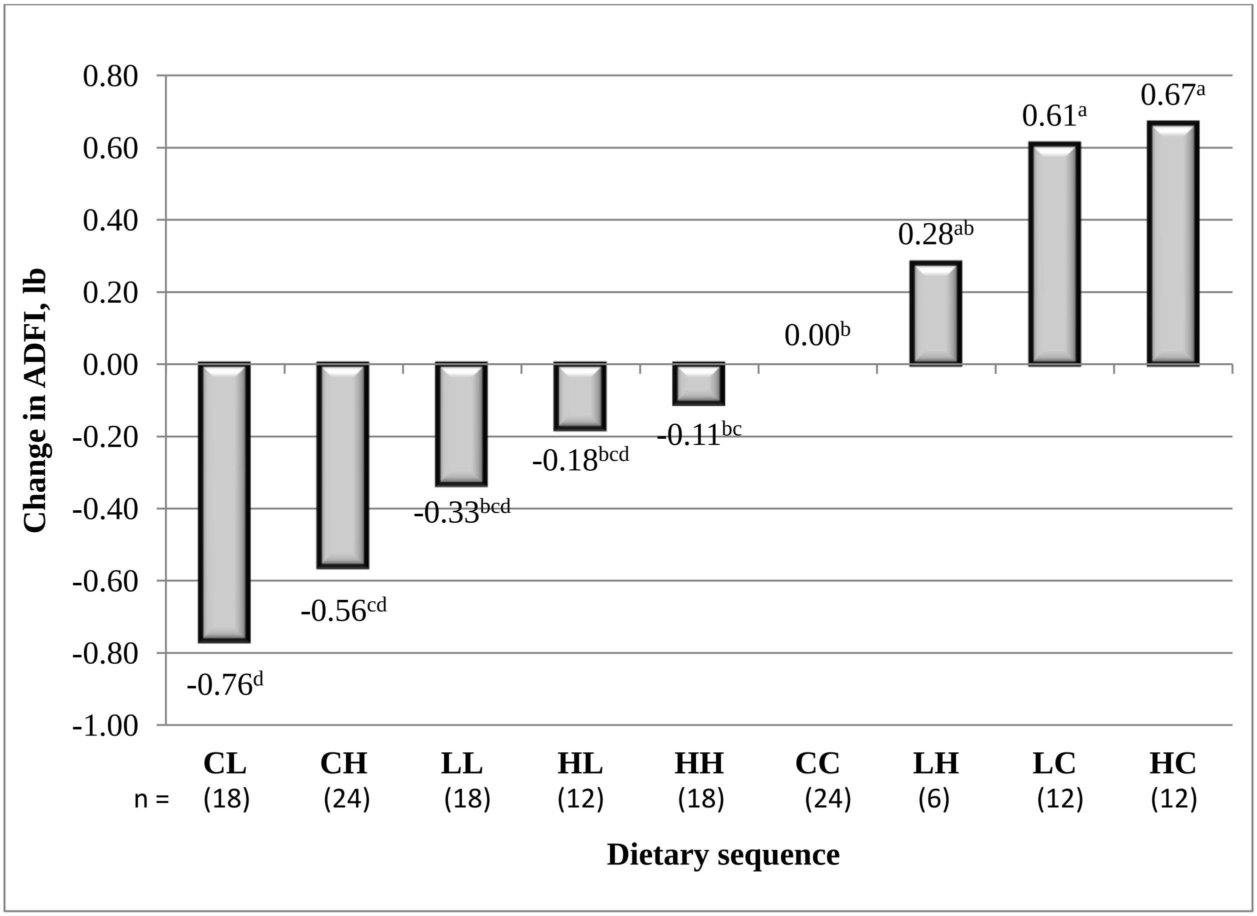

Figure 3. Effect of dietary sequence on ADFI. (Diet Sequence: CL = CON followed by Lo, CH = CON then Hi, LL = Lo then Lo, HL = Hi then Lo, HH = Hi then Hi, LH = Lo then Hi, CC = CON then CON, HC = Hi then CON, LC = Lo then CON). [abcd] Means without a common superscript differ ($P < 0.05$).

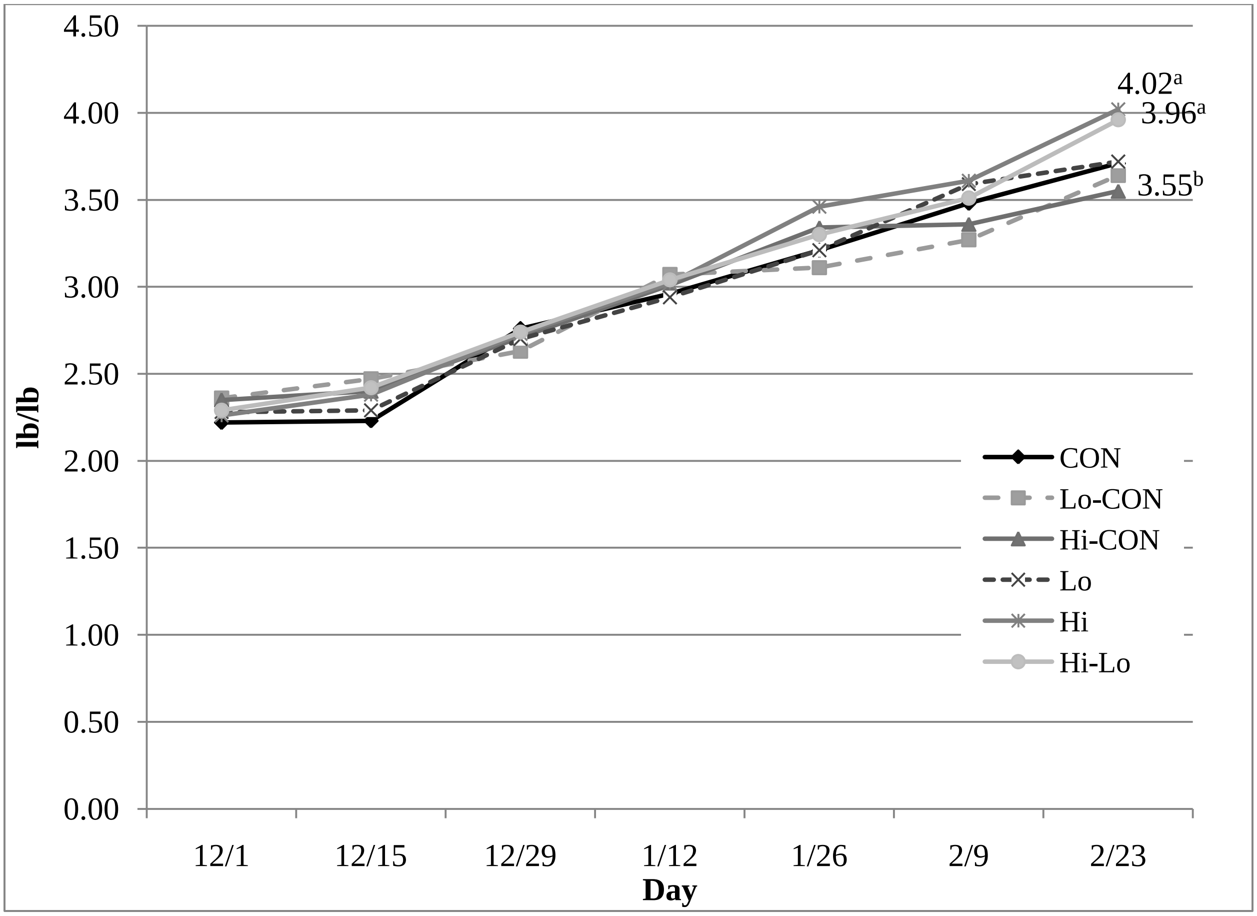

Figure 4. Effect of continuous and intermittent feeding of DDGS of varying quality on F/G.
[ab] Means within dates differ ($P < 0.05$). Time: $P < 0.05$, Diet*Time: $P < 0.05$.