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Impact of feeding diets containing reduced-oil distillers dried grains with solubles on growth performance and pork fat quality of growing-finishing pigs

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Abbreviation definitions:

ADFI = average daily feed intake
ADG = average daily gain
BW = body weight
CP = crude protein
DE = digestible energy
EE = ether extract; lipid
GE = gross energy
G:F = gain to feed ratio
HCW = hot carcass weight
IV = iodine value
LM = loin muscle
Lys = lysine
ME = metabolizable energy
NDF = neutral detergent fiber
NE = net energy
NRC = National Research Council
RO-DDGS = reduced-oil dried distillers grains with solubles
SID = standardized ileal digestible
WM = wheat middlings

Project objectives

The original objectives of the project were:

1. Determine growth performance and carcass characteristics of pigs fed diets containing 40% RO-DDGS (5, 8, and 11% crude fat levels) and formulated on a similar ME:SID Lys basis using current equations to determine ME and SID lysine content of RO-DDGS.
2. Determine the impact of formulating diets with two sources of RO-DDGS (5% crude fat and 11% crude fat) to a common dietary ME or NE content using the ME and NE prediction equations developed by Shurson and Kerr (2012).
3. Determine the impact of feeding diets containing wheat midds and RO-DDGS and formulated on a NE basis on growth performance and carcass characteristics of growing finishing pigs.

Description of work performed

Evaluation of ME predictions and the impact of feeding corn distillers dried grains with solubles with variable oil content on growth performance, carcass composition, and pork fat quality of growing-finishing pigs

A total of 432 pigs (initial BW: 25.8 ± 5.1 kg) were used to evaluate growth performance, carcass characteristics, and pork fat quality of growing-finishing pigs fed corn-soybean meal diets containing 40% distillers dried grains with solubles (DDGS) with variable ether extract (EE) content, but similar predicted ME concentration (3,232 to 3,315 kcal/kg predicted by a commercial service). Pigs were blocked by initial BW, and within blocks, pens were allotted randomly to 1 of 4 dietary treatments (9 pigs/pen, 12 replicates/treatment) in a 4-phase feeding program (26 to 50 kg, 50 to 75 kg, 75 to 100 kg, and 100 to 120 kg BW). Dietary treatments consisted of: 1) corn-soybean meal (CON), 2) 40% low-oil DDGS (5.9% EE; LOW), 3) 40% medium-oil DDGS (9.9% EE; MED), and 4) 40% high-oil DDGS (14.2% EE; HIGH). Diets contained similar concentrations of standardized ileal digestible AA and standardized total tract digestible P within each phase. Overall, ADFI of pigs fed CON was greater ($P < 0.05$) than MED and HIGH, and tended ($P < 0.10$) to be greater than LOW. No difference in ADFI was observed among DDGS treatments. Average daily gain of pigs fed LOW, MED, and HIGH was not different, but was less ($P < 0.05$) than pigs fed CON. However, pigs fed LOW had reduced ($P < 0.05$) G:F compared with the other treatments. Pigs fed CON had greater ($P < 0.05$) HCW, carcass yield, and LM area than those fed the DDGS diets, but there were no differences among DDGS treatments. No treatment differences were observed for backfat depth and percentage of carcass fat-free lean. Back, belly, and jowl fat iodine value of pigs fed LOW and MED were less ($P < 0.01$) than in pigs fed HIGH, but were greater ($P < 0.01$) than in pigs fed CON. Based on observed G:F, dietary ME content of LOW was less than MED, HIGH, and CON diets, indicating a slight overestimation of ME prediction for the low-oil DDGS source from the commercial service estimates and the Anderson et al. (2012) equations. In conclusion, including 40% DDGS in corn-soybean meal based diets negatively impacted the growth performance of growing-finishing pigs. However, reduced EE content of DDGS sources did not affect ADG, ADFI, and carcass composition, but improved pork fat quality. These results suggest that current ME predictions need to be refined for more accurate estimation of ME content for low-oil DDGS sources for swine.

Evaluation of NE predictions and the impact of feeding distillers dried grains with solubles (DDGS) with variable NE content on growth performance and carcass characteristics of growing-finishing pigs

Growing-finishing pigs (n = 432; initial BW = 22.0 ± 4.3 kg) were utilized to measure growth performance and carcass characteristics when fed 4 sources of DDGS with a wide range in predicted NE content. Pigs were blocked by initial BW, and within blocks, pens were randomly allotted to 1 of 4 dietary treatments (9 pigs/pen, 12 replicates/treatment). Dietary treatments consisted of 4 corn and soybean meal based diets containing 40% DDGS from different sources with increasing NE (as-fed) content predicted by a commercial service using a proprietary equation-based system: 1) source A with low NE (2,083 kcal/kg; LOW), 2) source B with medium-low NE (2,255 kcal/kg; ML), 3) source C with medium-high NE (2,469 kcal/kg; MH), and 4) source D with high NE (2,743 kcal/kg; HIGH). Diets met or exceeded nutrient requirements and were calculated to contain the same standardized ileal digestible Lys:NE within phases. Overall, ADFI of pigs fed ML was greater ($P < 0.05$) than for pigs fed MH and HIGH, but not different from LOW, and no differences were observed among LOW, MH, and HIGH. Pigs fed ML had similar ADG with LOW and HIGH, but less ($P < 0.05$) than that of pigs fed MH, and no differences were observed among LOW, MH, and HIGH. Gain:feed was reduced ($P < 0.02$) in pigs fed ML compared with other dietary treatments. No treatment differences ($P > 0.19$) were observed in HCW, carcass yield, backfat depth, LM area, and percentage of carcass fat-free lean. The NRC

(2012) model was used to estimate NE content of diets by matching the model-predicted G:F with the observed G:F. Using NRC (2012) NE content values for corn and soybean meal, NE content was calculated for DDGS sources A, B, C, and D to be 2,377, 1,924, 2,612, and 2,513 kcal/kg, respectively. Predicted NE values from 8 identified equations were calculated and compared with model-determined NE content of the 4 DDGS sources. Results indicated that G:F responses of pigs did not correspond to the NE estimates of the 4 DDGS sources provided by the commercial service, and suggest that NE content might have been overestimated for sources B and D, and underestimated for the sources A and C. Feeding 40% DDGS with less NE content increased ADFI and reduced ADG and G:F, but carcass traits were not affected when the difference of NE content is less than 700 kcal/kg among DDGS sources. In addition, current NE prediction systems need to be revised for better prediction of NE content among sources of DDGS.

Effects of feeding diets containing distillers dried grains with solubles and wheat middlings with equal predicted dietary NE on growth performance and carcass composition of growing-finishing pigs

This experiment evaluated the effects of feeding dried distillers grains with solubles (DDGS) and wheat middlings (WM) in diets with similar estimated NE content on growth performance and carcass characteristics of growing-finishing pigs. Pigs (n = 384; initial BW = 29.1 ± 3.6 kg) were blocked by initial BW, and within blocks, pens were allotted randomly to 1 of 4 dietary treatments (9 pigs/pen, 12 replicates/treatment) in a 4-phase feeding program (29 to 50 kg, 50 to 75 kg, 75 to 100 kg, and 100 to 120 kg BW). Dietary treatments were arranged in a 2 × 2 factorial design and formulated to consist of: 1) corn and soybean meal; CON, 2) CON with 30% DDGS, 3) CON with 15% WM, and 4) CON with 30% DDGS and 15% WM. Soybean oil was added to all diets except CON, to maintain similar dietary NE content within phases. Net energy values of 2,672, 2,087, 2,114, 2,113, and 7,545 kcal/kg (as-fed) were used for corn, soybean meal, DDGS, WM, and soybean oil, respectively. Diets met or exceeded nutrient requirements and were formulated to contain the same concentrations of standardized ileal digestible Lys within phases. No significant interactions for DDGS × WM × phase or DDGS × WM were observed for all growth performance criteria. Feeding 30% DDGS diets decreased ($P < 0.05$) ADFI (1.76 vs. 1.86 kg/d) and ADG (0.85 vs. 0.91 kg/d) in phase 1, but not in other phases. Gain:feed of pigs fed diets containing DDGS was not different during phase 1 to 3, but was greater ($P < 0.01$) in phase 4 (0.313 vs. 0.291), compared with that of pigs fed diets with no addition of DDGS. Feeding 15% WM did not affect ADFI or

G:F, but reduced ($P < 0.05$) ADG in phase 1 (0.86 vs. 0.90 kg/d) and not in phase 2 to 4. No DDGS × WM interaction was observed for carcass traits. Pigs fed diets containing 30% DDGS had reduced ($P < 0.01$) HCW (86.5 vs. 89.9 kg), carcass yield (72.3 vs. 73.6%), LM area (45.0 vs. 47.9 cm^2), and percentage of carcass fat free lean (52.1 vs. 53.4%), but backfat depth was not affected compared with pigs fed diets without DDGS. Adding 15% WM to diets reduced carcass yield (72.7 vs. 73.1%; $P < 0.05$) and HCW (87.7 vs. 88.7 kg; $P < 0.10$), but other carcass traits were not affected. In conclusion, overall ADG and G:F were not affected by feeding 30% DDGS or 15% WM when diets were formulated on the NE basis, but more accurate and dynamic estimation of NE content for DDGS sources is needed to optimize caloric efficiency at different physiological ages of pigs.

Results of technology or process assessed

In pork production, feed represents the largest proportion of the total production cost, and energy represents the greatest component of feed cost. As a result, swine nutritionists and pork producers are continually focusing on finding ways to improve caloric efficiency of pork production systems. This has become particularly important in recent years due to record high prices of traditional feed ingredients, such as corn and soybean meal, leading to increased use of non-traditional ingredients such as corn distiller's dried grains with solubles (DDGS) and wheat middlings. In fact, DDGS, which is a coproduct produced from dry-grind ethanol production, has been extensively used in U.S. swine diets to reduce feed cost. However, nutritionists are experiencing tremendous challenges when attempting to use accurate nutrient and energy loading values for DDGS in the diet formulation, because the inconsistent chemical composition and nutrient digestibility has caused large variability in ME and NE content among DDGS sources. The primary reason for increased variability in ME, NE, and nutrient content among DDGS sources has been due to the implementation of oil extraction by most ethanol plants. Partial oil extraction from this stillage has led to the assumption that ME and NE content of DDGS is reduced, and as a result, its feeding value is reduced. One approach to manage variability in chemical composition and energy content of DDGS is to use analyzed chemical composition and prediction equations to estimate ME and NE content of specific DDGS sources, but the precision and accuracy of these prediction equations have not been evaluated using growth performance studies.

In addition, feeding diets containing traditional high-oil DDGS sources has consistently resulted in reduced carcass pork fat quality. Pork fat quality has been commonly characterized by an increase in carcass fat iodine value (IV), and has been a major concern when including high levels of DDGS in growing-finishing diets. In order to achieve acceptable pork fat quality when feeding DDGS diets, IV prediction equations based on the concentration and composition of dietary lipid have been developed but require evaluation for their accuracy and precision.

Feeding high-fiber ingredients such as DDGS and wheat middlings (WM) often results in reduced pig growth and carcass responses, which appear to be a result of suboptimal feed intake and overestimation of the actual dietary energy available to growing-finishing pigs when using ME as the basis in diet formulation. The research described in this thesis addressed the effects of feeding DDGS sources with variable oil and energy content, as well as the effects of increasing dietary fiber, on growth performance, carcass composition, and pork fat quality of growing-finishing pigs. Furthermore, the precision and accuracy of ME and NE prediction equations for DDGS sources, as well as equations for predicting carcass fat IV were evaluated.

Our results showed that pigs fed DDGS with variable oil concentration, but similar ME content, had similar growth performance and carcass characteristics. Reduction in oil content of DDGS improved pork fat quality by reducing IV of carcass fat depots. Using ILLUMINATE® estimates or equations developed by Anderson et al. (2012): $DE = -2{,}161 + (1.39 \times GE) - (20.7 \times NDF) - (49.3 \times EE)$ and $ME = -261 + (1.05 \times DE) - (7.89 \times CP) + (2.47 \times NDF) - (4.99 \times EE)$ accurately predicted ME content of DDGS with medium and high oil content, but these models slightly overestimated the ME value of reduced-oil (< 6%) DDGS.

In addition, our results showed that ADFI was increased, ADG and G:F were decreased, but carcass traits were unaffected when pigs were fed DDGS sources with less NE content. Using ILLUMINATE® estimates and equations 4 and 5 from Noblet et al. (1994b) resulted in relatively precise and accurate NE estimates for DDGS sources.

Finally, our results showed that adding 30% DDGS or 15% WM to diets limited ADFI and ADG of pigs in early growing phase, but this effect diminished when pigs reached greater BW. In addition, DDGS had greater NE value in the late finishing phase than in the early feeding phases, which may be due to an increased ability of pigs to ferment dietary fiber with increasing physiological age. Formulating diets on a NE basis minimized the negative effects of feeding DDGS or WM on overall ADG and G:F, which has been often observed when diets were formulated on a ME basis.

In conclusion, reduced oil concentration in DDGS has minimal, if any effect on growth performance and carcass composition when ME content is accurately predicted. Due to inconsistent oil digestibility among DDGS sources, oil content is a poor single predictor of ME and NE values. However, the reduced oil concentration in DDGS generally improves pork fat quality when high levels of DDGS are added to growing-finishing diets, but the magnitude of this improvement is not proportional to the change in oil content among DDGS sources. Therefore, digestibility of dietary lipid should be included in future prediction models for estimating carcass fat IV. Our results confirm those previous studies showing that ME and NE content of DDGS sources are highly variable. Accurate and precise prediction equations can be a useful tool to manage this variability, but current prediction models need to be further refined to improve the estimation of ME and NE content by accounting for the differences in digestibility of lipid, fiber, and other nutrients among DDGS sources. In addition, we have proposed a novel approach to estimate energy content of feedstuffs using the NRC (2012) growth model and observed pig growth performance (gain:feed responses). Finally, increased dietary fiber from DDGS and WM appears to limit feed intake of pigs with light BW (< 55 kg), and decreases hot carcass weight and carcass yield. To optimize caloric efficiency of pigs fed high-fiber ingredients, diets should be formulated on the NE basis, and NE value of feedstuffs should be estimated dynamically for pigs at different stages of growth.

Benefit to Minnesota economic development

Approximately 20% the distillers dried grains with solubles (DDGS) produced in the U.S. (7 million metric tonnes) is being used in swine diets and fed at relatively high diet inclusion rates (30 to 40%) during the grower-finisher period. During the past several years, pork producers have saved as much as $10/pig in feed cost by adding these high amounts of DDGS to grower-finisher diets. There is no question that DDGS is a vitally important feed ingredient to pork producers. However, continuation of high DDGS feeding levels will depend on solving issues related to reduced oil content, increased nutrient content variation, and negative impacts on pork fat quality. Feeding high dietary inclusion rates (> 40%) of DDGS to growing-finishing pigs results in significant reductions in pork fat firmness, especially for the belly, which is a high value wholesale cut. As a result, pork processors are beginning to penalize pork producers by refusing to harvest pigs fed DDGS or by implementing a price discount system for pigs exceeding acceptable pork fat quality. Removal of high levels of DDGS from the diet for 3 to 6 weeks prior to harvest, or reducing dietary inclusion rates as pigs approach final market weight are two commons strategies used by nutritionists and pork producers to mitigate the negative impact of DDGS on pork fat quality. However, these strategies reduce overall utilization of DDGS in swine feeding programs.

Currently, more than 85% of U.S. ethanol plants are extracting corn oil from thin stillage before producing DDGS. This process results in the production of reduced-oil DDGS (RO-DDGS) with crude fat concentrations that range from 5 to 12%. Our previous research has shown that crude fat content of DDGS is poorly related to metabolizable energy (ME) content, and the reduction in ME content was much less than expected (Shurson and Kerr, 2012). As a result, prediction equations were developed and published (Anderson et al., 2012) to estimate ME content of DDGS sources regardless of crude fat content. However, these ME prediction equations had not been validated for their accuracy when used in formulating diets for growing-finishing pigs. Therefore, our first experiment involved conducting a growth performance trial to determine growth performance and carcass characteristics of pigs fed diets containing 40% RO-DDGS (5, 8, and 11% crude fat levels) and formulated on a similar ME:SID Lys basis using current equations to determine ME and SID lysine content of RO-DDGS. In addition, it is well documented that feeding diets containing increasing amounts of "high oil" DDGS linearly decreases pork carcass fat firmness, and may decrease carcass yield (Stein and Shurson, 2009). However, no studies have been conducted to determine the magnitude of improvement in carcass fat firmness by feeding diets containing 40% RO-DDGS with different crude fat but similar ME concentrations. This response was determined as a second objective in the first experiment of this project.

Nutritionists across the U.S. are adopting the NE system over the ME system because of the urgent need to improve nutritional efficiencies resulting from record high feed prices. Therefore, we conducted a second grower-finisher pig performance experiment using a novel approach to determine the net energy (NE) content of DDGS varying in oil content, by calculating NE content of RO-DDGS sources using the NRC (2012) model and actual growth performance data from feeding 4 sources of DDGS with different predicted NE content.

Finally, wheat midds have become a popular alternative feedstuff in grower-finisher swine diets because of its competitive price and potential positive impact on pork fat quality. However, limited studies have been conducted to evaluate growth performance of growing-finishing pigs fed diets containing wheat midds and DDGS. Therefore, we conducted a growth performance study to evaluate the accuracy of our NE prediction equations to estimate the energy content of RO-DDGS and formulate diets containing wheat midds on a NE basis, to determine if the using the NE system will improve growth performance of pigs compared with using the ME system. This was the third experiment conducted in this project.

Conclusions

Reduced oil concentration in DDGS has minimal, if any effect on growth performance and carcass composition when ME content is accurately predicted. Due to inconsistent oil digestibility among DDGS sources, oil content is a poor single predictor of ME and NE values. However, the reduced oil concentration in DDGS generally improves pork fat quality when high levels of DDGS are added to growing-finishing diets, but the magnitude of this improvement is not proportional to the change in oil content among DDGS sources. Therefore, digestibility of dietary lipid should be included in future prediction models for estimating carcass fat IV. Our results confirm those previous studies showing that ME and NE content of DDGS sources are highly variable. Accurate and precise prediction equations can be a useful tool to manage this variability, but current prediction models need to be further refined to improve the estimation of ME and NE content by accounting for the differences in digestibility of lipid, fiber, and other nutrients among DDGS sources. In addition, we have proposed a novel approach to estimate energy content of feedstuffs using the NRC (2012) growth model and observed pig growth performance (gain:feed responses). Finally, increased dietary fiber from DDGS and WM appears to limit feed intake of pigs with light BW (< 55 kg), and decreases hot carcass weight and carcass yield. To optimize caloric efficiency of pigs fed high-fiber ingredients, diets should be formulated on the NE basis, and NE value of feedstuffs should be estimated dynamically for pigs at different stages of growth.