RESEARCHREPORT

ANIMAL SCIENCE — Nutritional Efficiency Consortium

Title: Methods of Restoring Carcass Firmness and Other Post-Harvest Traits in Finishing Pigs Fed a High Level of Distillers Dried Grains with Solubles (DDGS) – **NPB #09-109**

Investigator: Gary L. Cromwell, PhD

Institution: University of Kentucky, Animal and Food Sciences Dept., Lexington, KY

Co-Investigators: Gregg K. Rentfrow, PhD and Merlin D. Lindemann, PhD, Miranda Ulery, MS, Graduate Student

Date Submitted: March 30, 2011

Industry Summary:

The large demand for corn for ethanol production has resulted in marked increases in corn prices and a resulting increase in feed costs for swine producers. The large amounts of distillers dried grains with solubles (DDGS), one of the major by-products of ethanol production, is now a viable and less expensive alternative feed ingredient for use in swine feeds. Questions are being asked regarding the amount of DDGS that can be used in swine feeds without causing reduced performance of pigs or soft bellies that are discriminated against by pork processors.

Previous research funded by the National Pork Checkoff showed that growing-finishing pigs could be fed as much as 45% DDGS in the diet with only a slight (2-3%) reduction in pig performance. However, this amount of DDGS in the diet caused softer bellies and high iodine values (a measure of the relative amount of unsaturated fatty acids in the carcass fat). However, in another study funded by the National Pork Checkoff, it was found that processing characteristics of pork bellies and eating quality of bacon, sausage, and loin chops were not negatively affected by this feeding this high dietary level of DDGS.

The objective of this study was to determine if withdrawal of a high level (45%) of DDGS from the diet during the final 2, 4, or 6 weeks of the finishing period or if the addition of a harder, more saturated fat (tallow) to a diet containing DDGS would prevent the softer bellies and high iodine numbers that occur when high levels of DDGS are fed. In addition, the study allowed us to further evaluate the effects of dietary inclusion of DDGS on the processing characteristics of cured bellies, physical characteristics of sliced bacon, and eating quality of bacon and loin chops.

These research results were submitted in fulfillment of the Nutritional Efficiency Consortium research projects. Contributing organizations for 2009 include: AgriSolutions, Inc., DPI Global, Iowa Pork Producers Association, Illinois Corn Marketing Board, Illinois Pork Producers Association, Kansas Pork Association, Missouri Pork Producers Association, Mississippi Pork Producers Association, National Pork Board, Nebraska Corn Board and the Utah Pork Producers Association.

This report is published directly as submitted by the projects principal investigator. This report has not been peer reviewed.

An experiment involved 168 crossbred pigs was conducted at the University of Kentucky. Seven dietary treatments were evaluated, which included a corn-soybean meal control diet, a similar diet with 45% DDGS fed continuously to the end of the experiment, or three treatments in which the DDGS was removed during the final 2, 4, or 6 weeks of the experiment followed by a corn-soybean meal diet. Two additional treatments were the same two diets with 5% added tallow. Each treatment was evaluated with six replications of three or five pigs per pen. Diets were fed in three phases from 81 to 267 lb body weight. The two diets without added tallow were formulated on a true ileal digestible (TID) lysine basis with 0.81, 0.70, and 0.55% TID lysine during the three phases. Adjustments were made in diets containing tallow to maintain the same TID lysine:ME ratio across all diets. The experiment was terminated on a replication basis when the average weights reached 265 lb. Three pigs per pen were killed for carcass information.

Over the entire experiment, average daily gains and daily feed intakes were reduced ($P < 0.05$) by about 8 to 9% in pigs fed DDGS continuously, but efficiency of feed utilization was not affected. Daily gain improved linearly ($P < 0.05$) with increasing time of DDGS withdrawal. Tallow addition to the DDGS diet prevented the growth reduction, and feed efficiency improved ($P < 0.05$) with tallow addition to both diets. Carcass yield was reduced by DDGS feeding, but withdrawal of DDGS improved dressing percent. Belly flex measurements were negatively impacted by DDGS feeding, but they improved to those of the control pigs when DDGS was withdrawn for 6 weeks. Polyunsaturated fatty acids (PUFA) in the fat increased ($P < 0.05$) when DDGS was fed, but the changes were moderated (linear, $P < 0.05$) with DDGS withdrawal time. Iodine values (IV) followed similar trends. Tallow addition had no positive effect on iodine values.

Bellies from the pigs were pumped with brine, smoked, and sliced into bacon at a commercial plant. Bacon slices were scored for shatter, then fried and scored for distortion, cook loss, and shrink, then evaluated by a trained sensory panel. DDGS inclusion had no affect on slicing yield of smoked bellies and it improved shatter scores ($P < 0.05$) of the bacon. After frying, there was more distortion, cooking loss, and shrink ($P < 0.05$) of bacon from pigs fed DDGS, and withdrawal time had no effect. Tenderness and flavor of bacon was not affected by DDGS. Tallow did not consistent affect any of the measures. Sensory attributes of loin chops were not affected by DDGS, but tallow increased off-flavor ($P < 0.05$).

In summary, this study clearly shows that some of the belly firmness problems and elevated iodine values in carcass fat that are associated with the feeding of high levels of DDGS in the diet can be overcome by withdrawing the DDGS from the diet during the final 4 to 6 weeks of the finishing period. A 4-week withdrawal produced acceptable iodine values (mean of backfat and belly fat of approximately 70). The addition of a hard fat such as beef tallow to the diet, however, was unsuccessful as a means of improving belly firmness and elevated iodine values of pigs fed DDGS at high dietary levels. Under the conditions of this study, the softer bellies, increased polyunsaturated fatty acids, and higher iodine values did not negatively impact bacon processing or eating quality of bacon or loin chops in pigs fed a high level of DDGS.

This study was supported with the National Pork Checkoff. For further information, contact Dr. Gary L. Cromwell, Animal and Food Sciences Department, University of Kentucky, Lexington, KY 40546 (gcromwel@uky.edu).

Keywords: Pig, distillers dried grains, belly firmness, iodine value, bacon, eating quality

Scientific Abstract:

An experiment involving 168 pigs (6 replications of 3 or 5 pigs/pen) was conducted to determine if feeding a high level of DDGS followed by varying withdrawal periods before slaughter, or if adding a more saturated fat (tallow) to diets containing DDGS (to reduce the dietary U:S fatty acid [FA] ratio) would offset the softer bellies that occur when high levels of DDGS are fed. Treatments (Trt) were (1) a corn-soybean meal diet or (2) a similar diet with

45% DDGS fed continuously or removed during the final 2, 4, or 6 weeks (Trt 3, 4, 5) followed by the corn-soybean meal diet. Trt 6 and 7 were the same as 1 and 2 except 5% tallow was added. Three diet phases were fed from 37 to 121 kg body weight. Diets for Trt 1-5 were formulated on a true ileal digestible (TID) lysine basis with 0.81, 0.70, and 0.55% TID lysine during the 3 phases. Adjustments were made in diets containing tallow to maintain the same TID lysine:ME ratio across all diets. Average daily gain (ADG), but not feed/gain (F/G), was reduced by DDGS inclusion ($P < 0.05$), but ADG improved linearly ($P < 0.05$) with increasing time of DDGS withdrawal. ADG tended to improve with tallow addition to the DDGS diet and F/G improved ($P < 0.05$) with tallow addition to both diets. Backfat (inner and outer) and belly fat were obtained for FA analysis. Polyunsaturated FA (PUFA) of the 3 fat depots) increased when DDGS was fed ($P < 0.05$), and the changes were moderated (linear, $P < 0.05$) with DDGS withdrawal time. Iodine values (IV) followed similar trends. Tallow addition had little effect on PUFA and IV, particularly in pigs fed DDGS. Bellies from 3 pigs per pen (18 per trt) were pumped with brine, smoked, and sliced (9 slices/2.54 cm) at a commercial plant. Bacon slices (10/slab) were scored for shatter; fried and scored for distortion, cook loss, and shrink; and evaluated by an 8-member trained sensory panel. DDGS inclusion did not affect bacon yield but it improved shatter scores ($P < 0.05$). Greater distortion, cooking loss, and shrink ($P < 0.05$) occurred in fried bacon from pigs fed DDGS with withdrawal time having no effect. Tenderness and flavor of bacon was not affected by DDGS. Tallow did not consistent affect any of the measures. Sensory attributes of loin chops were not affected by DDGS, but tallow increased off-flavor ($P < 0.05$). The results indicate that withdrawal of a high level of DDGS from the finishing diet for 4 to 6 wk partially restores belly firmness, but addition of a harder fat does not overcome softer bellies. Except for an improvement in shatter scores and increased cooking loss, most of the other traits and eating quality of bacon and loin chops were not affected by DDGS. This project was funded by the National Pork Checkoff.

Introduction:

Numerous ethanol plants have been built over the past few years and others will be coming on-line during the next several years. These plants have a high demand for corn which has resulted in a substantial increase in corn prices, hence greater feed costs for swine producers. Large amounts of DDGS are being produced as a by-product of ethanol production in these plants. Previous research at the University of Kentucky (Cromwell et al., 1983) and elsewhere has shown that relatively large amounts of DDGS originating from beverage alcohol plants can be used in growing-finishing diets without depressing performance. In addition, large variation in quality of DDGS has been found to exist (Cromwell et al., 1993; Spiehs et al., 2002).

Stein (2007) reviewed the literature on studies involving the feeding of DDGS for swine and found that the data were inconsistent with respect to the maximum amount of DDGS from ethanol plants that can be included in swine diets without negatively affecting performance or carcass firmness. His conclusions were that many swine producers are currently using up to 20% DDGS in finishing diets, but some producers are using greater inclusion rates, up to 35% DDGS, in diets without affecting performance or carcass quality. He further concluded that more research is needed to evaluate moderate to high levels of DDGS in diets on growth performance and belly firmness of hog carcasses.

A recent collaborative study that was funded by the National Pork Checkoff and conducted at nine universities (NCCC-42 Committee on Swine Nutrition) showed that high levels of DDGS, up to 45% of the diet, could be fed to growing-finishing pigs without depressing performance if the diets were formulated on a true ileal digestible lysine basis and if the diets were supplemented with lysine and tryptophan in order to keep the crude protein of the diet from becoming excessive; however, carcasses firmness decreased and iodine levels of the backfat increased with the higher levels of DDGS (Cromwell et al., 2009).

Although studies have clearly shown that belly firmness is reduced when high levels of DDGS are fed to pigs, little data exist on the effect of the softer carcasses on slicing efficiency of cured bellies and eating quality of bacon from these bellies. A recent study funded by the Pork Board indicated that softer bellies resulting from feeding a high level of DDGS did not affect slicing efficiency of bacon and did not affect eating quality or bacon, sausage, or loin chops (McClelland et al., 2009, 2010ab. However, these results need to be confirmed in additional studies. This study should provide some additional insight on these possible effects.

Objectives:

There were two objectives of this study. The first objective was to determine if withdrawing a high level (45%) of DDGS from the diet for 2, 4, or 6 weeks before the end of the finishing period will partially or totally prevent the belly softness and high iodine values associated with feeding this high level of DDGS throughout the entire growing-finishing period, and to further determine if DDGS feeding or DDGS withdrawal would affect the processing characteristics and eating quality of bacon and loin chops. The second objective was to determine if the inclusion of a highly saturated fat (tallow) to a diet containing 45% DDGS would offset the belly softness and high iodine values associated with feeding a high level of DDGS. Also, like the first objective, we wanted to see if the inclusion of tallow in the diet would affect the processing characteristics of cured bacon and eating quality of bacon and loin chops.

Materials and Methods:

Two experimental trials involving 168 crossbred pigs were conducted at the University of Kentucky in accordance with approved animal care guidelines. The two trials were identical except that the first one was conducted in the Animal Laboratory on the University of Kentucky campus and the second one was conducted at the University of Kentucky Swine Research Farm in Woodford County, approximately 20 miles from the UK campus. Because the protocol was the same for the two trials (except for the number of pigs per pen), the data were combined and analyzed as a single experiment.

The experiment consisted of seven treatments with six replications of three or five pigs per pen. The pigs averaged 37 kg initially and 121 kg at the end of the study. The pigs were housed in concrete, slatted-floor pens in environmentally controlled rooms.

The pigs were randomly allotted to treatments from outcome groups based on initial weight, gender, and litter to a randomized complete block design. Most of the pigs were barrows. In some replications, a gilt was used, but the barrow:gilt ratio across pens was identical within a given replication. Pigs were weighed and feed intake was determined at 2-week intervals and at weekly intervals toward the end of the experiment. Diets and water were provided on an ad libitum basis. The experiment was terminated on a replication basis when the pigs in the control pen of a given replication reached an average weight of approximately 120 kg.

The following seven treatments were evaluated in the experiment:

1. Corn-soybean meal diet (control)
2. Corn-soybean meal diet with 45% DDGS
3. Corn-soybean meal diet with 45% DDGS, then DDGS withdrawn the last 2 weeks
4. Corn-soybean meal diet with 45% DDGS, then DDGS withdrawn the last 4 weeks
5. Corn-soybean meal diet with 45% DDGS, then DDGS withdrawn the last 6 weeks
6. Corn-soybean meal diet plus 5% tallow
7. Corn-soybean meal diet with 45% DDGS plus 5% tallow

The control diet (treatment 1)) was a typical corn-soybean meal diet fortified with minerals and vitamins and was fed for the entire growing-finishing period. A second diet was the same as the control diet except that 45% DDGS was included. In treatment 2, the DDGS was fed throughout the experiment. In three additional treatments, the DDGS was withdrawn during the last 2, 4, or 6 weeks of the experiment, after which the pigs were returned to the control, corn-soybean meal diet. Diets in treatments 6 and 7 were the same as the diets in treatments 1 and 2, respectively, except tallow (a harder, more saturated fat) was included at a level of 5%. The intent was to determine if withdrawal of the DDGS during the final stages of finishing or if adding a harder fat to the diet would correct the belly softness associated with the feeding the high level of DDGS. Also, these treatments allowed us to evaluate the effects of DDGS withdrawal or tallow addition on processing characteristics of bacon and eating quality of bacon and loin chops.

The DDGS was obtained from a single plant at one time, and was supplied by ADM Alliance Nutrition, Decatur, IL. The DDGS was analyzed at a commercial laboratory and the results are shown in Table 1. The color, odor, and chemical composition were typical of a high quality DDGS product.

The tallow, provided by Griffin Industries, Falmouth, KY, came from a packing plant that processed only beef cattle. Although not analyzed, it should have contained approximately 52% saturated fatty acids and 48% unsaturated fatty acids, according to NRC (1998). By adding 5% tallow to the corn-soybean meal diet or the diet with 45% DDGS (which had a 4:1 ratio of unsaturated:saturated fatty acids) the unsaturated:saturated fatty acid ratio was reduced to approximately 1:1.

All diets, shown in Table 2, were formulated on a true ileal digestible (TID) lysine basis. The diets without tallow were formulated to contain 0.81, 0.70, and 0.55% TID lysine during the three phases with diet changes made at 60 and 92 kg body weight, respectively. The DDGS replaced corn and soybean meal, and crystalline lysine, threonine, tryptophan, and methionine were added to maintain constant TID levels of these amino acids in each phase. Adjustments were made in diets with added tallow to maintain the same ratios of these TID amino acids:ME as in diets without tallow. The calcium and digestible phosphorus levels were made constant across all diets during each phase. Because of the high level of digestible phosphorus in DDGS, very little or no supplemental phosphorus was needed in the diets containing the DDGS. All diets were fortified with salt, vitamins, and trace minerals to meet or exceed NRC (1998) standards, and tylosin was included in all diets.

At the end of the experiment, three pigs per pen (all pigs in the first trial and three barrows per pen that were closest to the pen average in the second trial) were given a tattoo and transported to the University of Kentucky meats laboratory. They were slaughtered using humane procedures. Carcass hot weight, 10th rib backfat, and 10th rib longissimus area were measured, and percentage of fat-free lean in the carcass was calculated using the National Pork Producers Council (2000) equation. A sample of backfat was taken at the 10th rib, and at the midpoint of the belly for determination of fatty acid composition. The backfat and belly fat core samples were packed in dry ice and sent by overnight mail to Dr. Michael Azain, University of Georgia, who determined the fatty acid profiles of fat from the inner and outer portions of the subcutaneous backfat and the belly fat.

Fatty Acid Profiles and Iodine Numbers.

The fatty acid profiles of the adipose tissues were determined by gas chromatography using a Shimadzu gas chromatograph (Model 14 A,Tokyo, Japan) with a flame ionization detector. Adipose tissue samples (50-100 mg) were transmethylated according to the method of Park and Goins (1994). Two mg of heptadecanoic acid (C 17:0) was added as an internal standard prior to processing. Fatty acid methyl esters in hexane were separated on a Supelcowax-10 fused capillary column (60 m × 0.53 mm, 0.5-mm film thickness; Supelco, Bellefonte, PA) under isothermal conditions. Column temperature was 220°C, injector temperature was 250°C, and detector temperature was 260°C. Injection volume was 0.5 uL and helium was the carrier gas. Peak identification was based on known standards (Nu Chek Prep, Elysian, MN). Iodine value was calculated as described by AOCS (1998) by multiplying the unsaturated fatty acids by factors and summing the result, as follows:

$$\text{Iodine number} = (16{:}1 \times 0.95) + (18{:}1 \times 0.86) + (18{:}2 \times 1.732) + (18{:}3 \times 2.616) + (20{:}1 \times 0.785) + (22{:}1 \times 0.723)$$

Belly Flex Measurements.

Bellies were removed from the right side of the chilled carcass and fabricated to comply with Institutional Meat Purchasing Specifications as described by the North American Meat Processors Association (2010). The spareribs and related cartilage were removed, bellies were squared (approximately 36 × 48 cm [14 × 19 in.]), and all remaining leaf fat was removed. The chilled, fresh bellies with the skin on were then centered, fat side down, on a 7.6 cm (3 in.) diameter polyvinyl chloride (**PVC**) pipe mounted perpendicular to a board marked with a 2.54-cm (1-in.) grid matrix (Figure 1). Lateral and vertical flexes were determined from the degree of belly flex relative to the grid matrix. A vertical belly flex of zero meant the belly was parallel to the floor and completely stiff. A lateral belly flex of 10 cm meant that the belly flexed to a point where there was 10 cm between the end of the squared belly and a vertical line directly below the center of the supporting PVC pipe. The cranial and caudal halves of each belly were measured and the results of the 2 halves were averaged. A lower lateral and a higher vertical flex indicated a softer, more flexible belly. The belly flex measurements were determined in a room maintained at 7°C.

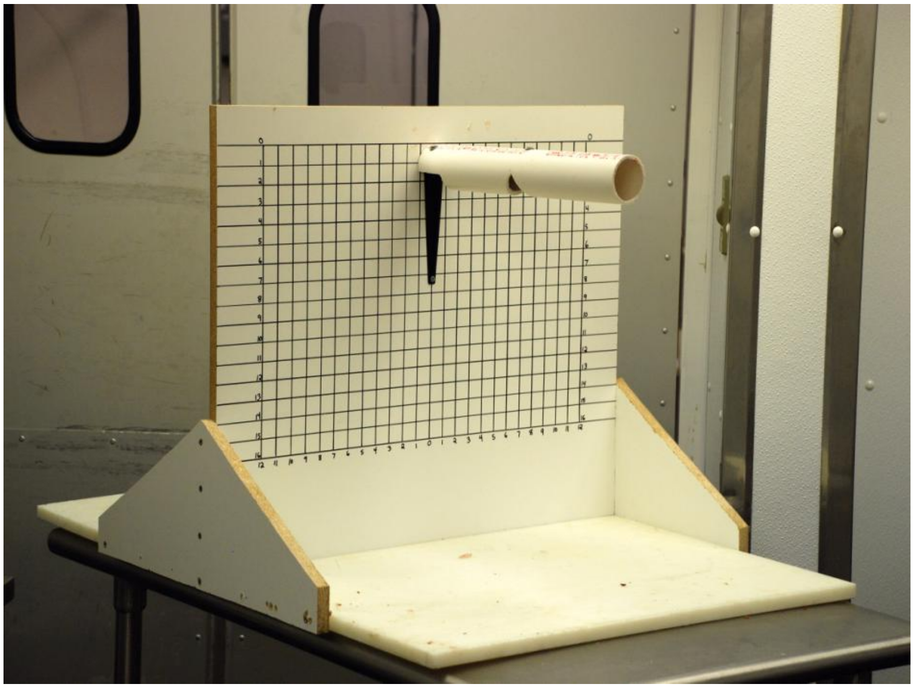

Figure 1. Apparatus used to measure belly flex values.

Belly/Bacon Processing and Measurements.

Uncooked bellies were skinned, transported to a commercial packing plant (Burger's Smokehouse, California, MO). Belly weights were taken at the plant before and after pumping each belly with a typical commercial brine (water, salt, sugar, sodium phosphate, sodium erythorbate, and nitrite) at 112% of the initial green weight. They were allowed to hang and drain to approximately 110% of the green weight. They were then hung by a bacon comb attached at the flank end and thermal processed in a smokehouse according to the plants commercial protocol. Following processing, the bacon slabs were removed from the smokehouse and chilled (-4º C) overnight. The following morning, individual bacon slabs were weighed to determine smokehouse yield, then they were placed in a tempering cooler to facilitate optimal pressing and slicing. Full bacon slabs were pressed using a commercial bacon press, then sliced by a high-speed slicer at nine slices per inch. The bacon slices were then boxed for transport back to the University of Kentucky Meat Science Laboratory.

The bacon was evaluated for slicing yield by removing the end pieces presenting comb marks and any incomplete slices and weighing the remaining portion of the slab. Percent slice yield was calculated as follows:

Slice yield (%) = 100 x (weight of bacon slices / weight of smoked belly)

A shatter test was evaluated as described by Rentfrow et al. (2003). A trained individual evaluated duplicate samples from each section of each bacon slab. A shatter, or fracture, was determined if lines of separation, either vertical or lateral, were seen within the fat on a slice of raw bacon when rolled over the evaluator's finger. Each piece of bacon analyzed was evaluated in four quadrants. A score of 1 indicated no cracks or shattering with increasing severity up to a score of 6. A score of 6 was given if there were spider web cracks throughout the quadrant (see Figure 2).

A subjective measurement of distortion was measured on cooked pieces of bacon. Two slices of bacon from each of the five sections of a slab of bacon were taken and cooked on an electric griddle at approximately 163^{o}C for 2.25 minutes per side. The bacon was removed from the griddle and allowed to cool on an absorbent paper towel for 10 minutes before evaluating the bacon using a 5-point distortion scale as previously described by Rentfrow et al. (2003). A score of 1 represented a slice that was mostly flat with increasing numbers through 5 for increasing severity of curling. A score of 5 was assigned when there was no flat area on the bacon slice (see Figure 3). The slices were measured for weight and length in the uncooked state then again as a cooked slice for cooking weight loss and shrink, respectively. The cooked weight was taken after the slice was allowed to cool on an absorbent paper towel for 10 minutes.

Analysis of loins

The loins were removed from the carcass and allowed to bloom for a minimum of 30 minutes before subjective analysis. They were split at the 10th rib and subjectively scored for color, marbling, and firmness. Pork carcass evaluation scorecards were used (AMSA, 1991) to score them from 1 to 6 for color (1 = pale pinkish gray to white, 6 = dark purplish red). Marbling was scored as a value between 1 and 10 (1 = 1 % intramuscular fat, 10 = 10% intramuscular fat). A firmness score was assessed as a value between 1 and 5 (1= extremely soft, 5= extremely firm).

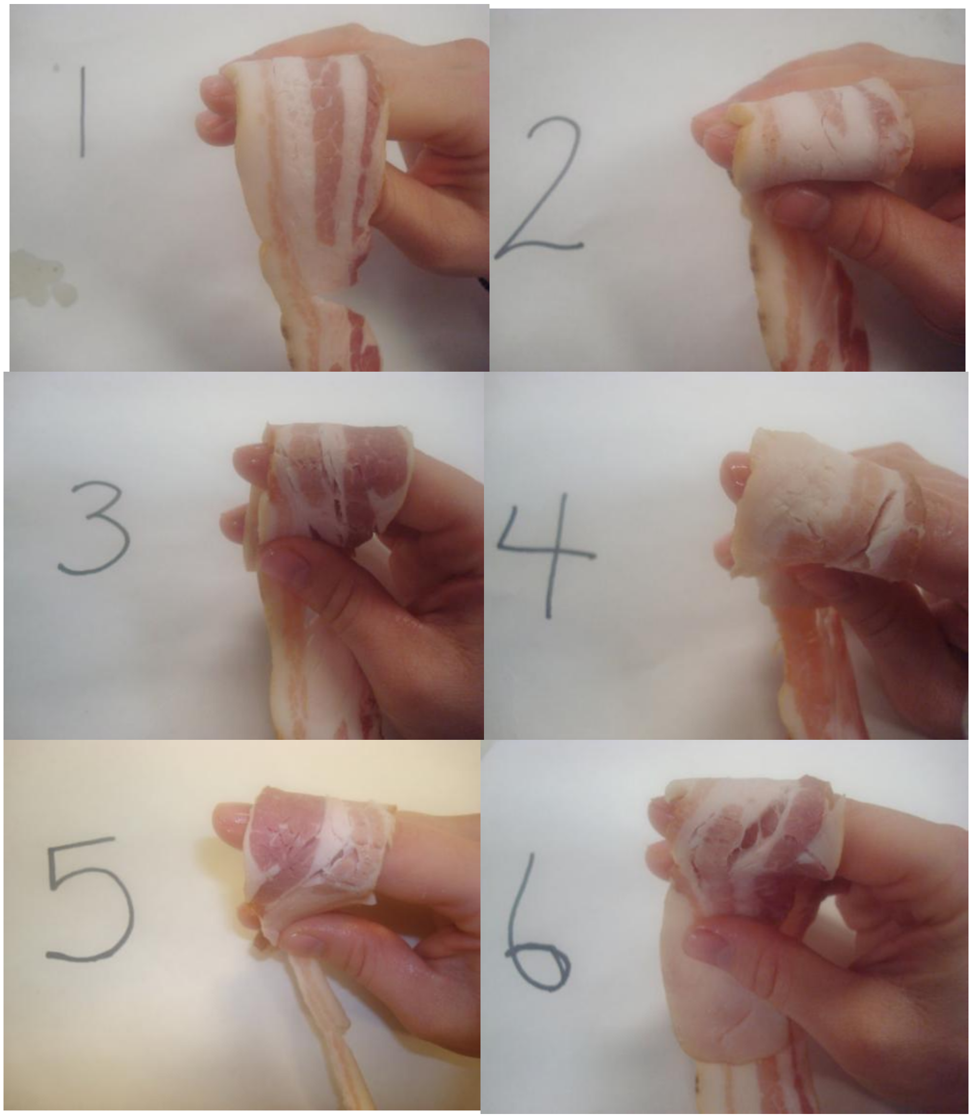

Figure 2. Fresh bacon shatter scoring scale

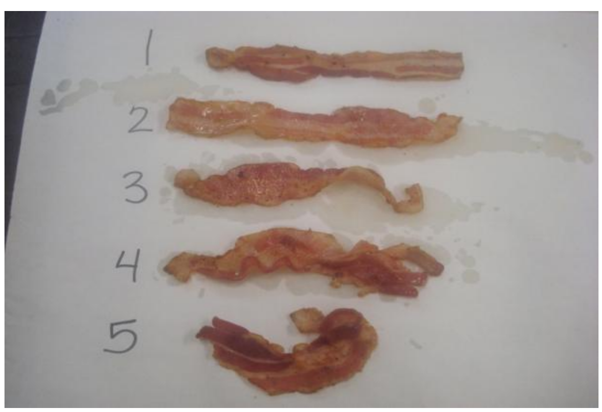

Figure 3. Cooked bacon distortion scoring scale

Objective color (L*, a*, b*) numbers was determined initially (day 0) and on days 1, 2, 3, 4, 5, 6, and 7 at approximately the same time each day and at two locations on loin chops overwrapped with PVC and using a HunterLab Miniscan XE Plus Colorimeter (HunterLab Associates, Reston, Va.) with illuminant D65, 2.54 cm diameter aperture and a 10° standard observer. The colorimeter was standardized with black and white tiles overwrapped with PVC. Spectral reflectance was determined every 10 nm over the 400 – 700 nm range.

TBARS Evaluation of Loin Chops

Loin chops were removed posterior to 10th and 11th rib juncture. They were cut at a thickness of 1.3 cm (½ in.) and stored at 4° C under cool fluorescent lighting (1,300 LUX) for 0 and 7 d for thiobarbituric acid reactive substances (TBARS) analysis. The thiobarbituric acid assay by Witte et al. (1979) and Schmedes and Holmer (1989) measured the secondary products of lipid oxidation. The chemical reagents used in this method include an 11% trichloroacetic acid (TCA) solution and a 20 mM thiobarbituric acid (TBA) solution. Duplicate meat samples were homogenized with the 11% TCA solution then filtered. An equal amount of the filtrate and the 20 mM TBA solution were mixed and incubated at 25° C for 20 hours. Absorbance of each sample was read at 532 nm at the end of the 20-hr incubation period with a spectrophotometer (Shimadzu UV-2401 PC spectrophotometer, Shimadzu Inc., Columbia, MD, USA) and reported as TBARS.

Sensory Panel Evaluation of Bacon

The bacon was evaluated for sensory characteristics using a trained 8-member taste panel. Each panelist was trained for determining texture and flavor of bacon using slices from the control treatment. During the sensory test, the bacon strips were cooked on an electric griddle at approximately 163° C for 2.25 minutes per side. They were allowed to cool on an absorbent paper towel for at least 10 minutes, then cut into equal portions for sampling. The panelists received 8 to 12 samples per session and asked to evaluate the texture and flavor of each piece. Their answers were recorded on a hedonic scale using the values 1 through 5. For the evaluation of texture, a score of 1 was tough and chewy, a score of 3 was the most desirable, and a score of 5 indicated bacon that was very crisp, crumbly, and tender. For the evaluation of flavor, a score of 1 was for no off-flavor and a score of 5 was a very intense off-flavor of any kind. The panelists were asked to comment on any unusual flavors or textures for each piece.

Objective Evaluation of Loin Chops for Tenderness

Loin chops were measured for shear force (tenderness) and sensory characteristics. Chops were cut from deboned loins 24 hours post-slaughter, placed into vacuum-packed bags and frozen at -18 to -20° C. They were thawed overnight prior to each test. Chops were cut 2.54 cm (1 in.) thick and cooked to an internal temperature of 70° C using a clamshell electric grill. They were then placed in a cooler at 4° C for 4 hours. For each chop, five 1.27-cm (½ in.) diameter cores were removed parallel to the muscle fiber orientation and sheared with a Warner-Bratzler shear device attached to a Shimadzu EZ-S Texture Analyzer at a cross-head speed of 200 mm/min (Shimadzu Scientific Instruments, Inc. Columbia, MD). The chops were removed from the cooler no more than four at a time and allowed to reach room temperature before testing. The five cores were averaged for each chop sample.

Sensory Panel Evaluation of Loin Chops

Loin chops were evaluated for sensory attributes using an 8-member trained panel. Each member was trained for determination of tenderness and juiciness of loin chops. Chops cut to 2.54 cm (1 in.) thick were thawed at 4° C in a walk-in cooler overnight prior to the sensory evaluation. Each session evaluated eight chops at a time with two sessions per day, 2 hours apart. The chops were cooked on a clamshell electric griddle to an internal temperature of 70° C, then allowed to rest for 10 min before cutting into 1.27 cm (½ in.) pieces and served to the panelists warm. Panelists were given water to cleanse their pallet between each sample. Each sample was evaluated using an 8-point scale for both tenderness and juiciness and a 5-point scale for intensity of off-flavor. A score of 1 on the tenderness scale indicated a very chewy and tough piece and 8 indicated a very tender piece. A score of 1 on the juiciness scale indicated a very dry piece and a score of 8 indicated a very juicy piece. For off-flavor, a score of 0 indicated no off-flavor and 5 indicated a very intense off-flavor.

Statistical Analysis of the Data.

All of the data were subjected to statistical analysis using the GLM procedure of SAS with pen considered the experimental unit. The control diet (treatment 1) was contrasted to the DDGS diet fed throughout the experiment (treatment 2), then linear and nonlinear trends were evaluated for length of withdrawal period for treatments 2, 3, 4, and 5. A second set of contrasts compared a factorial arrangement of treatments 1, 2, 6, and 7 with main effects of diet (treatments 1 and 6 vs. 2 and 7) and tallow addition (treatments 1 and 2 vs. 6 and 7) and the interaction of diet type and added tallow. A probability level of 5% was considered statistically significant.

Results:

For each group of responses, there are two sets of tables in this section. One table gives means for treatments 1, 2, 3, 4, and 5, which are the corn-soybean meal control diet, the DDGS diet for the entire experimental period, and DDGS withdrawal for the final 2, 4, or 6 weeks, respectively, followed by the corn-soybean meal diet. A second table gives means for treatments 1 and 2 (the corn-soybean meal control diet and the diet with DDGS fed continuously) along with these same two diets with 5% added tallow (treatments 6 and 7).

The performance data, carcass data, and belly flex data are shown in Tables 3 and 4. In this experiment, both growth rate and feed intake were significantly ($P < 0.05$) reduced in pigs fed 45% DDGS for the entire test period, but feed:gain was not affected. The 8% reduction in daily gain and 9% reduction in daily feed intake in this study were considerably greater than what we found in previous studies in which this same level of DDGS was fed (Cromwell et al., 2009). Withdrawal of DDGS and switching pigs back to the corn-soybean meal control improved gains and feed intakes overall, with a linear ($P < 0.05$) effect of withdrawal time. Tallow addition to the DDGS diet improved gains to nearly equal to those of pigs fed the corn-soybean meal control diet. As expected, feed efficiency improved significantly ($P < 0.05$) with tallow addition to both the control and DDGS diets.

Pigs fed DDGS had significantly reduced carcass yields, smaller loin eye areas, and lower fat-free lean percentages than those fed the corn-soybean meal control diet. Some of these differences were undoubted associated with the significantly lower slaughter weight of the DDGS-fed pigs. Dressing percentage improved with increased withdrawal time (quadratic, $P < 0.05$). Changes in backfat, loin eye area, and fat-free lean percentages occurred with increased DDGS withdrawal time. Tallow addition improved carcass yield of pigs fed DDGS, but this response was probably associated with the improvement in growth rate from tallow addition and, therefore, pigs that were heavier at slaughter ($P < 0.05$).

Based on belly flex measures, the bellies of pigs fed DDGS continuously were softer and less firm ($P < 0.05$) than those of control pigs. Withdrawing DDGS for the final 2, 4, and 6 weeks linearly ($P < 0.05$) increased the firmness of the bellies. The 6-week withdrawal resulted in belly flex measurements that were similar to those of pigs fed the corn-soybean meal control diet. Adding tallow to the diet had essentially no effect on belly firmness.

Tables 5 and 6 show the fatty acid composition of the outer and inner backfat and the belly fat and the iodine values of the fat. In all cases, the percentages of saturated and monounsaturated fatty acids decreased and polyunsaturated fatty acids (especially C18:3 linoleic acid) increased in the fat of pigs fed DDGS continuously compared with the control group. Iodine values were increased by feeding DDGS ($P < 0.05$). Withdrawal of DDGS in the finishing period resulted in linear changes ($P < 0.05$) in these fatty acids in the direction of the control group and linear reductions in iodine values, but they did not equal the percentages of those fatty acids or iodine values in the controls. Tallow addition to the DDGS diet resulted in only a slight reduction in the percentage of polyunsaturated fatty acids and had no beneficial effect on iodine values.

Tables 7 and 8 show characteristics of cured bellies and bacon from the pigs. Slicing efficiency (i.e., the percentage of cured bellies that were recoverable as slices of acceptable bacon) was quite variable among bellies, ranging from less than 33% to 93%, but treatment means were not significantly different, ranging from 65.5 to 71.2%. Quality of fresh bacon slices, measured as shatter scores, were actually better ($P < 0.05$) in pigs fed DDGS. However, during the frying of bacon slices, there were greater cooking loss, more shrink in length and more curling in bacon ($P < 0.05$) from the DDGS group. Except for slightly tougher bacon in the pigs fed tallow ($P < 0.05$), sensory attributes of the fried bacon was not different among treatment groups and all were in the acceptable range.

Tables 9 and 10 show some characteristics of loin chops from the pigs. Subjective scores of color, marbling, and firmness of the loin eye muscle after the loins were split at the 10^{th} rib did not differ among the treatment groups. Objective color scores of packaged loin chops over a 7-day period are shown graphically in Figures 4 to 9. In general, the samples became darker with other color changes through day 3, then reversed to initial or near-initial degrees of lightness by day 7. There were significant treatment differences on certain days, but the results are somewhat difficult to interpret. In general, loins of pigs fed DDGS tended to be lighter in color (not significant; Figure 4) and tallow feeding tended to produce darker colored loins ($P < 0.05$; Figure 5). The feeding of DDGS produced loins with more of a red color on certain days than those fed the corn-soybean meal control ($P < 0.05$; Figures 6 and 7), and the corn-soybean meal diet resulted in more of a yellow tone to the loin chops on certain days than those fed DDGS ($P < 0.05$; Figures 8 and 9). TBARS, a measure of fatty acid oxidation and shelf life, of packaged loin chops were not different initially or on day 7 among the seven treatments, but the TBARS did increase over the 7 day period. The increase, however, was less ($P < 0.05$) in pigs fed the tallow diets.

When tenderness of cooked loin samples was objectively assessed by shear force test, there were no differences among treatments (Tables 9 and 10). However, when tenderness was subjectively assessed by a taste panel, loin chops from pigs fed DDGS were less tender than controls, and tenderness improved linearly ($P < 0.05$) with length of withdrawal period. Tallow addition tended to make chops less tender (not significant) and resulted in more ($P < 0.01$) off-flavor.

Discussion:

The results of this experiment confirm our previous studies supported by the Pork Board that growing-finishing pigs can efficiently utilize rather large amounts of DDGS (in this instance, 45%) in the diet provided that diets are formulated in such a way that dietary protein level does not become excessive. As before, in this study diets were formulated on a true digestible lysine basis and supplemental amino acids (lysine, threonine, tryptophan, and methionine) were used. In this experiment, we did find that both growth rate and feed intake were significantly ($P < 0.05$) reduced in pigs fed DDGS, but feed:gain was not affected. The 8% reduction in daily gain and 9% reduction in daily feed intake in this study were more than what we found in the previous study in which this same level of DDGS was fed (Cromwell et al., 2009). However, when DDGS was withdrawn from the late finisher diet and pigs were switched to a corn-soybean meal control diet, the overall performance improved linearly with length of withdrawal. The 4-week withdrawal resulted in gains and feed intakes that were similar to those of the control pigs over the entire test period. Interesting, tallow addition to the DDGS diet improved pig growth rates to levels of the controls. With respect to growth performance, these results suggest that maximum pig performance can be achieved with the feeding of a high level (45%) of DDGS if the DDGS is withdrawn the final 4 weeks of the finishing period or if 5% fat is also added to the diet.

Carcass traits of pigs in this study were not consistently influenced by feeding DDGS, although some of the differences could be attributed to the lighter final weight of the pigs due to the fact that all pigs were on test for a constant period of time. However one consistent response that we did observe was a marked decrease in belly firmness due to a change in the fatty acid composition of the fat in pigs fed DDGS. In all areas of the carcass where we sampled the fat, the percentage of polyunsaturated fat percentage significantly increased and the percentages of saturated and monounsaturated fatty acids significantly decreased when DDGS was fed, resulting in higher iodine values. The changes are attributed to the highly unsaturated fat (especially the polyunsaturated fatty acid, C18:3 [linoleic acid]) in the corn-based DDGS. Withdrawal of the DDGS from the diet (especially for 6-weeks), however, markedly improved the belly firmness scores (Figures 10 and 11), the percentages of polyunsaturated fatty acids (Figure 12) and the iodine values (Figure 13). Tallow addition, however, did not improve any of these characteristics. Iodine values were in the acceptable range with a 4-week withdrawal of DDGS.

Packers often complain that softer bellies result in difficulty in slicing bacon slabs and lower slicing yields. However, we did not find this to be the case in our study, nor did we find this in our previous experiment supported by the pork board (McClelland et al., 2009, 2010b). In fact, when we plotted the slicing yield of bellies against the iodine values of all the pigs in the study, there was no relationship of the two traits (Figure 14). None of the other characteristics of fresh or cooked bacon, nor taste panel evaluation of bacon were negatively affected by feeding the high level of DDGS. Tallow had little effect on bacon quality or sensory evaluation of bacon, expect for a slight increase in off-flavor.

Except for some minor changes in color, other characteristics of fresh loin chops also were not affected by feeding the high level of DDGS (as previously found by McClelland et al., 2010a), by withdrawal of DDGS from the diet, or by adding tallow to the diet. Sensory traits of cooked loin chops were highly acceptable for all treatment groups.

In summary, this study clearly shows that some of the belly firmness problems and elevated iodine values in carcass fat that are associated with the feeding of high levels of DDGS in the diet can be overcome by withdrawing the DDGS from the diet during the final 4 to 6 weeks of the finishing period. A 4-week withdrawal produced acceptable iodine values (mean of backfat and belly fat of approximately 70). The addition of a hard fat such as beef tallow to the diet, however, was unsuccessful as a means of improving belly firmness and elevated iodine values of pigs fed DDGS at high dietary levels. Under the conditions of this study, the softer bellies, increased polyunsaturated fatty acids, and higher iodine values did not negatively impact bacon processing or eating quality of bacon or loin chops in pigs fed a high level of DDGS.

References:

AMSA. 1991. Guidelines for meat color evaluation. American Meat Science Assoc., Kansas City, MO and National Live Stock and Meat Board. Chicago, IL.

AOCS. 1998. Official Methods and Recommended Practices of the AOCS. 5th ed. Amer. Oil Chem. Soc., Champaign, IL.

Cromwell, G. L., T. S. Stahly, H. J. Monegue and J. R. Overfield. 1983. Effect of distillers dried grains with solubles on performance and bone traits of growing-finishing swine. J. Anim. Sci. 57(Suppl. 1):49.

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.

Cromwell, G. L., M. J. Azain, O. Adeola, S. K. Baidoo, S. D. Carter, T. D. Crenshaw, S. W. Kim, D. C. Mahan, P.

S. Miller, and M. C. Shannon. NCCC-42 Committee on Swine Nutrition. 2009. Corn distillers dried grains with solubles (DDGS) in diets for growing-finishing pigs – a cooperative study. J. Anim. Sci. 87(E-Suppl. 3):81.

McClelland, K.M., G.A. Anderson, R.B. Cox, M.D. Lindemann, G.L. Cromwell, and G. Rentfrow. 2009. Effects of distillers dried grains with solubles on belly/bacon quality. Abstr. 80, Proc. 62nd Reciprocal Meat Conference.

McClelland, K.M., G. Rentfrow, G.L. Cromwell, and M.D. Lindemann. 2010a. Effects of distillers dried grains with solubles on pork longissimus and sausage quality. Abstr. 49P, Proc. 63rd Reciprocal Meat Conference.

McClelland, K.M., G.K. Rentfrow, G.L. Cromwell, M.D. Lindemann, and M.J. Azain. 2010b. Effects of corn distillers dried grains with solubles (DDGS) on quality traits of pork. J. Anim. Sci. 88:(E-Suppl. 3):90.

North American Meat Processors Association. 2010. The Meat Buyers Guide, 6th ed. North American Processors Association, Reston, VA.

National Pork Producers Council. 2000. Pork Composition & Quality Assessment Procedures. Natl. Pork Producers Counc., Des Moines, IA.

NRC. 1998. Nutrient Requirements of Swine. National Research Council, National Academy Press, Washington, DC.

Park, P, and R. E. Goins. 1994. In situ preparation of flame for analysis of fatty acid composition in food. J. Food Sci. 59:1262-1266.

Rentfrow, G., C.A. Stahl, K.R. Maddock, M.L. Linville, G. Allee, T.E. Sauber, and E.P. Berg. 2003. The effects of diets containing conventional corn, conventional corn and choice white grease, high oil corn, and high oil high oleic corn on belly/ bacon quality. Meat Sci. 64:459-466.

Schmedes, A., and G. Holmer, 1989. A new thiobarbituric acid (TBA) method for determining free malonidialdehyde (MDA) and hyproperoxides selectively as a measure of lipid peroxidations. JAOCS 66:813-817.

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, Hans H. 2007. Distillers dried grains with solubles (DDGS) in diets fed to swine. HHS-Swine Focus-001.2007 publication. Dept. of Animal Science, University of Illinois, Urbana.

Witte, V. C., Krause, G. F., and Bailey, M. E. 1979. A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. J. Food Sci. 35:582-585.

Acknowledgements: Appreciation is extended to the National Pork Board for supporting this research with a grant-in-aid from the Pork Checkoff. Appreciation is also extended to ADM Alliance Nutrition, Decatur, IL for providing the DDGS and amino acids for the study.

Table 1. Composition of the DDGS used in the study

	%
Dry matter	92.1
Crude protein	28.1
Crude fat	10.3
Acid detergent fiber	15.9
Neutral detergent fiber	26.8
Crude fiber	7.2
Ash	4.3
Calcium	0.07
Phosphorus	0.90
Sulfur	0.58
Lysine	0.73
Tryptophan	0.18
Threonine	0.96
Methionine	0.51
Cysteine	0.33
Isoleucine	1.04
Valine	1.35

Table 2. Composition of diets (%, as fed basis)

	Phase I				Phase II				Phase III			
Treatment:	1	2-5	6	7	1	2-5	6	7	1	2-5	6	7
Corn	72.98	39.85	66.38	33.25	77.55	45.12	71.14	38.92	83.54	50.84	76.97	44.73
Soybean meal, dehulled	24.50	13.00	26.00	14.50	20.00	7.70	21.30	8.80	14.00	2.00	15.50	3.00
DDGS	--	45.00	--	45.00	--	45.00	--	45.00	--	45.00	--	45.00
Tallow	--	--	5.00	5.00	--	--	5.00	5.00	--	--	5.00	5.00
L-lysine-HCl	--	0.22	0.03	0.25	--	0.25	0.03	0.28	--	0.24	0.01	0.27
L-threonine	0.04	--	0.07	0.03	0.03	--	0.06	0.03	0.04	--	0.06	0.03
L-tryptophan	--	0.03	0.01	0.04	--	0.03	0.01	0.04	--	0.03	0.01	0.04
DL-methionine	0.05	--	0.09	0.04	0.05	--	0.09	0.04	0.05	--	0.09	0.04
Dicalcium phosphate	1.35	0.83	1.35	--	1.30	--	1.30	--	1.30	--	1.30	--
Ground limestone	0.58	1.40	0.57	1.40	0.60	1.42	0.60	1.42	0.60	1.42	0.60	1.42
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamins, trace minerals	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Tylan-40	0.05	0.05	0.05	0.05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
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
Calculated analysis												
Protein, %	17.7	22.1	17.9	22.3	15.9	20.0	16.0	20.1	13.6	17.8	13.8	17.8
Total lysine, %	0.93	0.99	0.98	1.05	0.81	0.87	0.85	0.91	0.64	0.71	0.68	0.74
TID lysine, %[1]	0.81	0.81	0.86	0.86	0.70	0.70	0.74	0.74	0.55	0.55	0.59	0.59
TID threonine, %	0.61	0.61	0.65	0.65	0.54	0.54	0.57	0.57	0.46	0.46	0.49	0.49
TID tryptophan, %	0.18	0.18	0.19	0.19	0.16	0.16	0.17	0.17	0.12	0.12	0.13	0.13
TID methionine+cystine, %	0.59	0.59	0.62	0.62	0.54	0.54	0.58	0.58	0.48	0.48	0.52	0.52
Fat, %	2.36	5.92	7.19	10.74	2.45	6.02	7.28	10.85	2.56	6.13	7.39	10.96
NDF, %	9.2	17.0	8.7	16.5	9.2	17.1	8.7	16.6	9.3	17.1	8.8	16.6
Ca, %	0.62	0.62	0.62	0.62	0.61	0.61	0.61	0.61	0.59	0.59	0.59	0.59
Total P, %	0.62	0.61	0.62	0.60	0.60	0.58	0.59	0.57	0.57	0.56	0.56	0.55
Digestible P, %	0.28	0.28	0.28	0.28	0.27	0.27	0.27	0.27	0.26	0.26	0.26	0.26
ME, Mcal/kg	3.32	3.30	3.53	3.51	3.33	3.31	3.54	3.51	3.34	3.31	3.54	3.52

[1] The true ileal digestible (TID) lysine requirement (NRC, 1998) for pigs at the midpoint of the three phases is 0.80, 0.67, and 0.53%, respectively.

Table 3. Effects of feeding a high level (45%) of DDGS and withdrawal of DDGS from the finisher diet on performance, carcass traits, and belly firmness

Treatment:	1	2	3	4	5
Diet:	Corn-Soy	DDGS	DDGS	DDGS	DDGS
Withdrawal of DDGS:	-	-	2-wk	4-wk	6-wk
No. replications	6	6	6	6	6
No. pigs[1]	24	23	23	23	24
Avg initial wt, kg	37.4	37.6	37.4	37.4	37.3
Avg final wt, kg[2]	122.4	116.4	120.4	120.8	120.2
Performance					
Avg daily gain, kg[2,3]	1.00	0.92	0.95	0.97	0.96
Avg daily feed intake, kg[2,3]	2.80	2.55	2.68	2.93	2.78
Feed:gain[5]	2.81	2.81	2.84	3.05	2.90
Carcass[1]					
Avg slaughter wt, kg[2,3]	124.0	117.8	121.2	121.2	122.5
Avg hot carcass wt, kg[2,3]	93.0	86.5	91.0	90.7	91.3
Hot carcass yield, %[2,4]	75.0	73.4	75.1	74.8	74.5
Backfat, 10th rib, mm[3]	22.8	24.5	22.1	25.3	27.4
Loin eye area, sq. cm[2]	48.9	44.9	47.8	45.8	45.7
Carcass fat-free lean, %[2,4]	50.7	49.5	50.8	49.2	48.3
Belly flex measurements[6]					
Lateral, cm[2,3]	15.0	11.3	12.1	13.0	15.2
Vertical, cm[2,3]	31.8	33.7	33.4	32.7	31.4

[1] Carcass data are based on six replicates of three pigs per pen, or 18 pigs per treatment.

[2] Corn-soybean meal vs DDGS with no withdrawal ($P < 0.05$).

[3] Linear effect of withdrawal time ($P < 0.05$).

[4] Quadratic effect of withdrawal time ($P < 0.05$).

[5] Cubic effect of withdrawal time ($P < 0.05$).

[6] A larger lateral score and a smaller vertical score indicates a firmer belly.

Table 4. Effects of supplementing a hard fat (tallow) to a corn-soybean meal diets without and with a high level of DDGS on performance, carcass traits, and belly firmness

Treatment:	1	2	6	7
Diet:	Corn-Soy	DDGS	Corn-Soy + 5% tallow	DDGS + 5% tallow
No. replications	6	6	6	6
No. pigs[1]	24	23	24	24
Avg initial wt, kg	37.4	37.6	37.3	37.5
Avg final wt, kg[2,3,4]	122.4	116.4	122.1	122.4
Performance				
Avg daily gain, kg[3,4]	1.00	0.92	0.98	0.99
Avg daily feed intake, kg[2,4]	2.80	2.55	2.39	2.43
Feed:gain[2]	2.81	2.81	2.45	2.48
Carcass[1]				
Avg slaughter wt, kg[3]	124.0	117.8	123.3	122.8
Avg hot carcass wt, kg[3]	93.0	86.5	93.2	91.4
Hot carcass yield, %[2,3]	75.0	73.4	75.6	74.4
Backfat, 10th rib, mm	22.8	24.5	22.8	24.1
Loin eye area, sq. cm[3]	48.9	44.9	50.5	45.7
Carcass fat-free lean, %[3]	50.7	49.5	51.2	49.6
Belly flex measurements[5]				
Lateral, cm[3]	15.0	11.3	13.8	10.8
Vertical, cm[3]	31.8	33.7	32.2	33.9

[1] Carcass data are based on six replicates of three pigs per pen, or 18 pigs per treatment.

[2] Main effect of tallow ($P < 0.05$).

[3] Main effect of DDGS ($P < 0.05$).

[4] Tallow × DDGS interaction ($P < 0.05$).

[5] A larger lateral score and a smaller vertical score indicates a firmer belly.

Table 5. Effects of feeding a high level (45%) of DDGS and withdrawal of DDGS from the finisher diet on fatty acid composition and iodine values[1]

Treatment:	1	2	3	4	5
Diet:	Corn-Soy	DDGS	DDGS	DDGS	DDGS
Withdrawal of DDGS:	-	-	2-wk	4-wk	6-wk
Fat composition of outer backfat[3]					
Fatty acid composition, % of total					
Saturated fatty acids[2,3]	38.3	30.9	32.3	35.9	35.2
Monounsaturated fatty acids[2,3]	48.3	43.3	44.6	44.0	46.2
Polyunsaturated fatty acids[2,3]	13.4	25.8	23.2	20.1	18.6
Iodine value[2,3,4]	64.4	80.8	77.5	74.3	71.3
Fat composition of inner backfat					
Fatty acid composition, % of total					
Saturated fatty acids[2,3]	44.8	36.0	38.3	40.5	42.3
Monounsaturated fatty acids[2,3]	43.4	37.7	39.9	40.9	41.5
Polyunsaturated fatty acids[2,3]	11.8	26.2	21.7	18.5	16.2
Iodine value[2,3,4]	57.4	76.7	71.0	66.4	63.2
Fat composition of belly fat					
Fatty acid composition, % of total					
Saturated fatty acids[2,3]	37.6	32.4	33.7	34.7	35.2
Monounsaturated fatty acids[2,3]	49.9	44.9	46.5	47.5	48.6
Polyunsaturated fatty acids[2,3]	12.4	22.7	19.8	17.7	16.2
Iodine value[2,3,4]	64.2	77.1	73.8	71.1	69.6

[1] Fat samples from carcasses from six replicates of three pigs per pen, or 18 carcasses per treatment.

[2] Corn-soybean meal vs DDGS with no withdrawal ($P < 0.05$).

[3] Linear effect of withdrawal time ($P < 0.05$).

[4] An iodine value of 70 or less is desirable. A score of 73-74 is generally considered to be the maximum that is acceptable by packers.

Table 6. Effects of supplementing a hard fat (tallow) to a corn-soybean meal diets without and with a high level of DDGS on fatty acid composition and iodine values[1]

Treatment:	1	2	6	7
Diet:	Corn-Soy	DDGS	Corn-Soy + 5% tallow	DDGS + 5% tallow
Fat composition of outer backfat				
Fatty acid composition, % of total				
Saturated fatty acids[2,3]	38.3	30.9	33.9	29.5
Monounsaturated fatty acids[2,3]	48.3	43.3	52.0	46.7
Polyunsaturated fatty acids[3]	13.4	25.8	14.1	23.8
Iodine value[3,5]	64.4	80.8	68.9	80.5
Fat composition of inner backfat				
Fatty acid composition, % of total				
Saturated fatty acids[2,3,4]	44.8	36.0	40.0	34.0
Monounsaturated fatty acids[2,3]	43.4	37.7	46.3	41.5
Polyunsaturated fatty acids[3,4]	11.8	26.2	13.7	24.5
Iodine value[2,3,4,5]	57.4	76.7	63.3	77.1
Fat composition of belly fat				
Fatty acid composition, % of total				
Saturated fatty acids[2,3]	37.6	32.4	34.4	30.4
Monounsaturated fatty acids[2,3]	49.9	44.9	53.1	47.8
Polyunsaturated fatty acids[3]	12.4	22.7	12.5	21.8
Iodine value[2,3,5]	64.2	77.1	67.3	78.4

[1] Fat samples from carcasses from six replicates of three pigs per pen, or 18 carcasses per treatment.

[2] Main effect of tallow ($P < 0.05$).

[3] Main effect of DDGS ($P < 0.05$).

[4] Tallow × DDGS interaction ($P < 0.05$).

[5] An iodine value of 70 or less is desirable. A score of 73-74 is generally considered to be the maximum that is acceptable by packers.

Table 7. Effects of feeding a high level (45%) of DDGS and withdrawal of DDGS from the finisher diet on cured belly and bacon characteristics[1]

Treatment:	1	2	3	4	5
Diet:	Corn-Soy	DDGS	DDGS	DDGS	DDGS
Withdrawal of DDGS:	-	-	2-wk	4-wk	6-wk
Green belly wt, kg	4.52	4.08	4.22	4.33	4.56
Pumped belly wt, kg	5.03	4.39	4.58	4.80	5.11
Smoked belly wt, kg	4.19	3.70	3.84	4.02	4.27
Sliced belly wt, kg	2.79	2.41	2.64	2.82	3.06
Slicing yield of cured bellies, %	66.1	65.6	69.3	69.2	70.3
Shatter score of fresh bacon slices, %[2,3]	4.35	3.45	3.71	3.65	3.99
Following frying of bacon					
Weight loss, %[2]	55.5	58.5	56.7	56.5	58.0
Shrink in length, %[2]	27.8	30.8	30.3	30.2	30.6
Distortion score[2,4]	3.16	3.52	3.49	3.53	3.45
Sensory attributes of fried bacon[5]					
Texture score[6]	3.07	3.00	3.00	3.11	2.99
Off-flavor score[7]	1.78	1.94	1.87	1.80	1.99

[1] Bellies from six replicates of three pigs per pen, or 18 bellies per treatment.

[2] Corn-soybean meal vs DDGS with no withdrawal ($P < 0.05$).

[3] Fresh bacon slices were given scores of 1 to 6, with 1 representing no visual cracks or shattering and scores of 2, 3, 4, 5, and 6 representing increases in severity of shattering within the fat of the bacon slice. A score of 6 represented a “spider-web” consistency of shattering.

[4] Cooked bacon slices were scored using a 5-point scale where 1 represented a flat slice after cooking, with scores of 2, 3, 4, and 5 representing increased severity of curling scores. A score of 5 indicated a slice that completely curled with no flat areas on the slice.

[5] Taste panel evaluation was performed by an eight-member panel.

[6] Texture scores: 1 to 5 with 1 = extremely tough and chewy, 3 = desirable, and 5 = very tender or crumbly.

[7] Off-flavor scores: 1 to 15 with 1 = no off-flavor and 5 = intense off-flavor.

Table 8. Effects of supplementing a hard fat (tallow) to a corn-soybean meal diets without and with a high level of DDGS on cured belly and bacon characteristics[1]

Treatment:	1	2	6	7
Diet:	Corn-Soy	DDGS	Corn-Soy + 5% tallow	DDGS + 5% tallow
Green belly wt, kg	4.52	4.08	4.43	4.39
Pumped belly wt, kg	5.03	4.39	4.93	4.79
Smoked belly wt, kg	4.19	3.70	4.13	4.06
Sliced belly wt, kg	2.79	2.41	2.89	2.93
Slicing yield of cured bellies, %	66.1	65.6	69.8	71.1
Shatter score of fresh bacon slices, %[2,5]	4.35	3.45	4.05	3.54
Following frying of bacon				
Weight loss, %	55.5	58.5	56.2	57.4
Shrink in length, %[2]	27.8	30.8	29.3	29.7
Distortion score[4,6]	3.16	3.52	3.41	3.21
Sensory attributes of fried bacon[7]				
Texture score[3,8]	3.07	3.00	2.94	2.84
Off-flavor score[9]	1.78	1.94	1.74	1.94

[1] Bellies from six replicates of three pigs per pen, or 18 bellies per treatment.

[2] Main effect of DDGS ($P < 0.05$).

[3] Main effect of tallow ($P < 0.05$).

[4] Tallow × DDGS interaction ($P < 0.05$).

[5] Fresh bacon slices were given scores of 1 to 6, with 1 representing no visual cracks or shattering and scores of 2, 3, 4, 5, and 6 representing increases in severity of shattering within the fat of the bacon slice. A score of 6 represented a "spider-web" consistency of shattering.

[6] Cooked bacon slices were scored using a 5-point scale where 1 represented a flat slice after cooking, with scores of 2, 3, 4, and 5 representing increased severity of curling scores. A score of 5 indicated a slice that completely curled with no flat areas on the slice.

[7] Taste panel evaluation was performed by an eight-member panel.

[8] Texture scores: 1 to 5 with 1 = extremely tough and chewy, 3 = desirable, and 5 = very tender or crumbly.

[9] Off-flavor scores: 1 to 5 with 1 = no off-flavor and 5 = intense off-flavor.

Table 9. Effects of feeding a high level (45%) of DDGS and withdrawal of DDGS from the finisher diet on loin chop characteristics[1]

Treatment:	1	2	3	4	5
Diet:	Corn-Soy	DDGS	DDGS	DDGS	DDGS
Withdrawal of DDGS:	-	-	2-wk	4-wk	6-wk
Subjective scores[2]					
Color	2.94	2.89	2.53	2.78	2.67
Marbling	1.89	1.61	1.69	2.00	1.94
Firmness	2.94	2.89	2.67	2.83	2.78
TBARS, mg/kg[3]					
Day 0	0.64	0.59	0.59	0.59	0.59
Day 7	1.44	1.19	1.29	1.24	1.29
Change	0.84	0.59	0.69	0.64	0.69
Shear force of cooked chops, kg	3.20	3.27	3.00	2.83	3.21
Sensory attributes of cooked chops					
Tenderness[4,6]	5.24	4.70	4.81	5.08	5.27
Juiciness[4]	5.02	4.64	4.61	4.99	4.91
Off-flavor[5]	0.50	0.38	0.43	0.31	0.39

[1] Loins from six replicates of three pigs per pen, or 18 loins per treatment.

[2] Color score of 1 to 10, with 1 = pale, pinkish gray to white and 10 = dark, purplish red. Marbling score of 1 to 10, with 1 = 1% marbling and 10 = 10% marbling. Firmness score of 1 to 5, with 1 = extremely soft and 5 = extremely firm.

[3] TBARS represent the amount of fatty acid oxidation that has occurred. A higher score represents greater oxidation of the fat due to presence of more unsaturated fatty acids; this may reduce shelf life and increase the chances of off-flavor.

[4] Tenderness and juiciness scores: 1 to 5 with 1 = tough and dry; 5 = extremely tender and juicy.

[5] Off-flavor scores: 0 to 5 with 0 = no off-flavor; 5 = very intense off-flavor

[6] Linear effect of withdrawal time ($P < 0.05$).

Table 10. Effects of supplementing a hard fat (tallow) to a corn-soybean meal diets without and with a high level of DDGS on loin chop characteristics[1]

Treatment: Diet:	1 Corn-Soy	2 DDGS	6 Corn-Soy + 5% tallow	7 DDGS + 5% tallow
Subjective scores of fresh loin[2]				
Color	2.94	2.89	3.22	3.00
Marbling	1.89	1.61	1.89	1.72
Firmness	2.94	2.89	2.94	2.67
TBARS, mg/kg[3]				
Day 0	0.64	0.59	0.59	0.59
Day 7	1.44	1.19	1.14	1.09
Change[6]	0.84	0.59	0.54	0.50
Shear force of cooked chops, kg	3.20	3.27	3.17	3.22
Sensory attributes of cooked chops				
Tenderness[4]	5.24	4.70	4.91	4.72
Juiciness[4]	5.02	4.64	4.72	4.38
Off-flavor[5,6]	0.50	0.38	1.78	1.62

[1] Loins from six replicates of three pigs per pen, or 18 loins per treatment.

[2] Color score of 1 to 10, with 1 = pale, pinkish gray to white and 10 = dark, purplish red. Marbling score of 1 to 10, with 1 = 1% marbling and 10 = 10% marbling. Firmness score of 1 to 5, with 1 = extremely soft and 5 = extremely firm.

[3] TBARS represent the amount of fatty acid oxidation that has occurred. A higher score represents greater oxidation of the fat due to presence of more unsaturated fatty acids; this may reduce shelf life and increase the chances of off-flavor.

[4] Tenderness and juiciness scores: 1 to 5 with 1 = tough and dry; 5 = extremely tender and juicy.

[5] Off-flavor scores: 0 to 5 with 0 = no off-flavor; 5 = very intense off-flavor

[6] Main effect of tallow ($P < 0.05$).

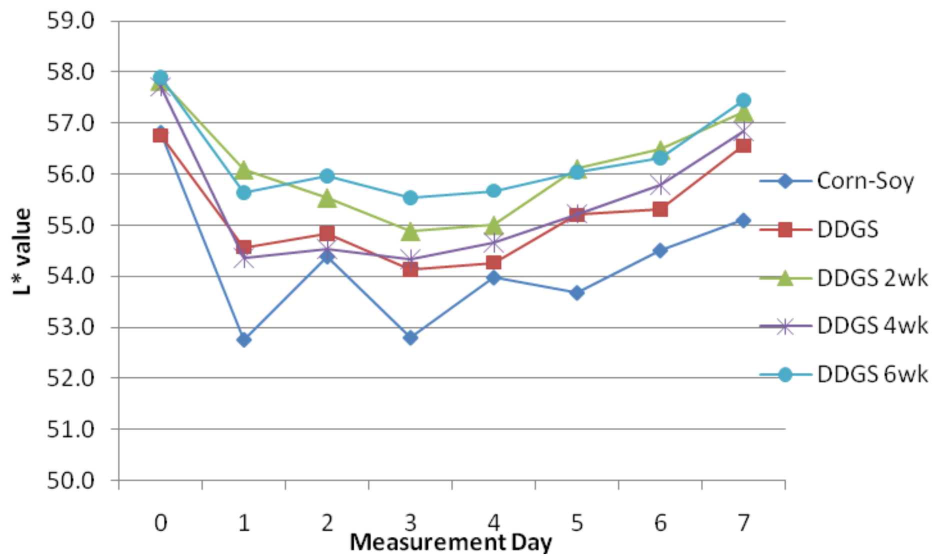

Figure 4. Effect of feeding a high level of DDGS (45%) and withdrawing DDGS on the L* value of loin chops over a 7 day period. L* value of 0 = black; L* value of 100 = white.

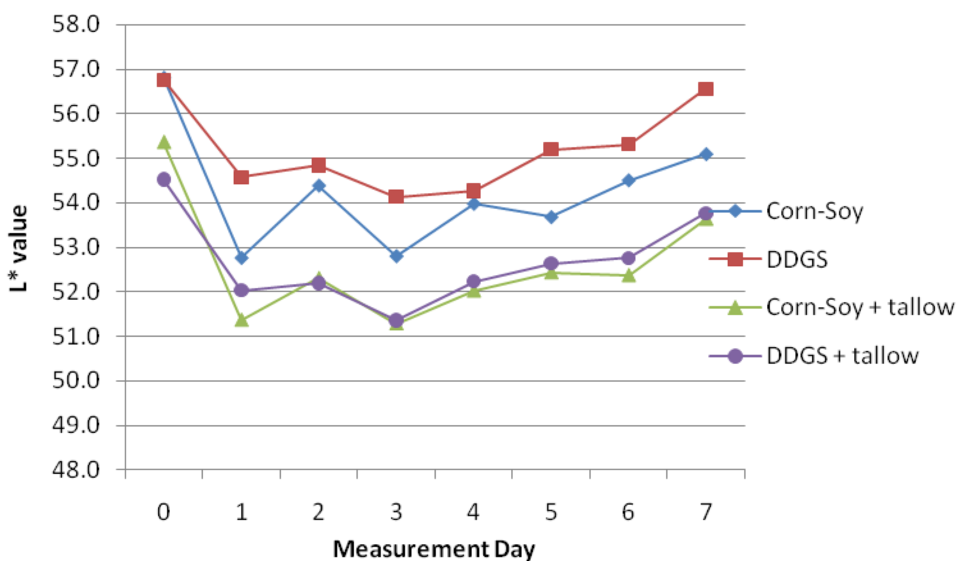

Figure 5. Effects of supplementing a hard fat (tallow) to a corn-soybean meal diet without and with a high level of DDGS on the L* values of loin chops over a 7 day period. L* value of 0 = black; L* value of 100 = white. Main effect of tallow ($P < 0.05$) on all days.

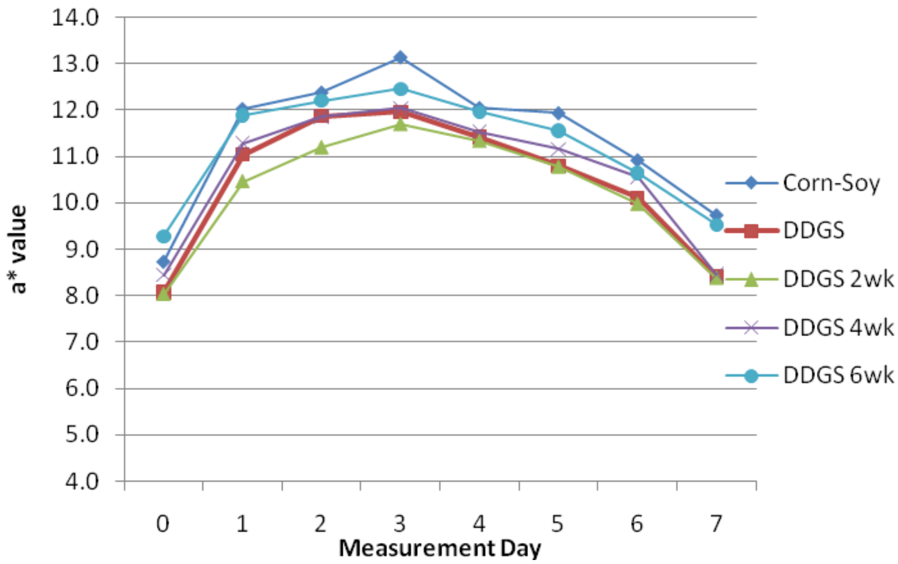

Figure 6. Effect of feeding a high level of DDGS (45%) and withdrawing DDGS on the a* value of loin chops over a 7 day period. Higher a* values mean less of a red color and more of a green color. Corn-soybean meal vs. DDGS ($P < 0.05$) on days 0, 3, and 5. Linear ($P < 0.05$) effect of withdrawal time on day 0.

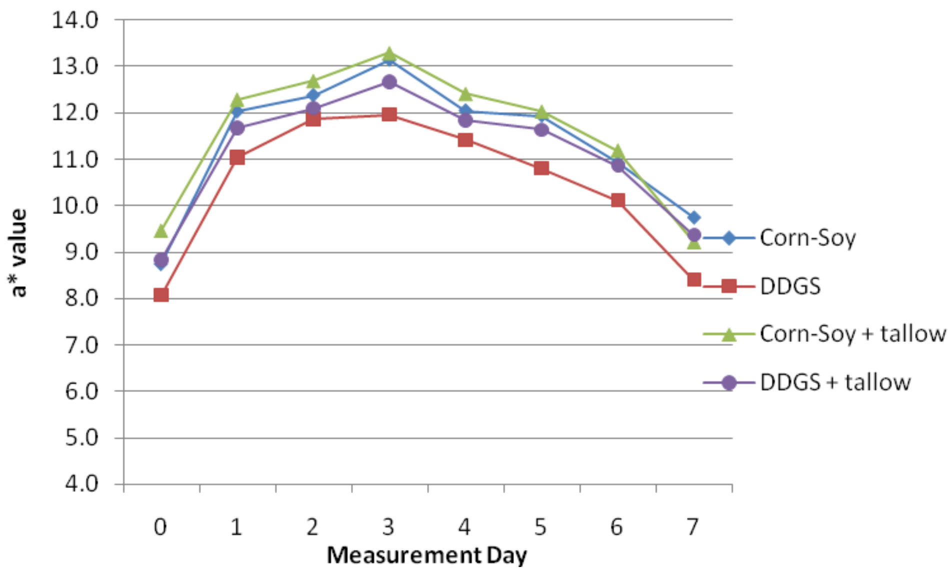

Figure 7. Effects of supplementing a hard fat (tallow) to a corn-soybean meal diet without and with a high level of DDGS on a* values of loin chops over a 7 day period. Higher a* values mean less of a red color and more of a green color. Main effect of DDGS ($P < 0.05$) on days 0 and 3. Main effect of tallow ($P < 0.05$) day 0.

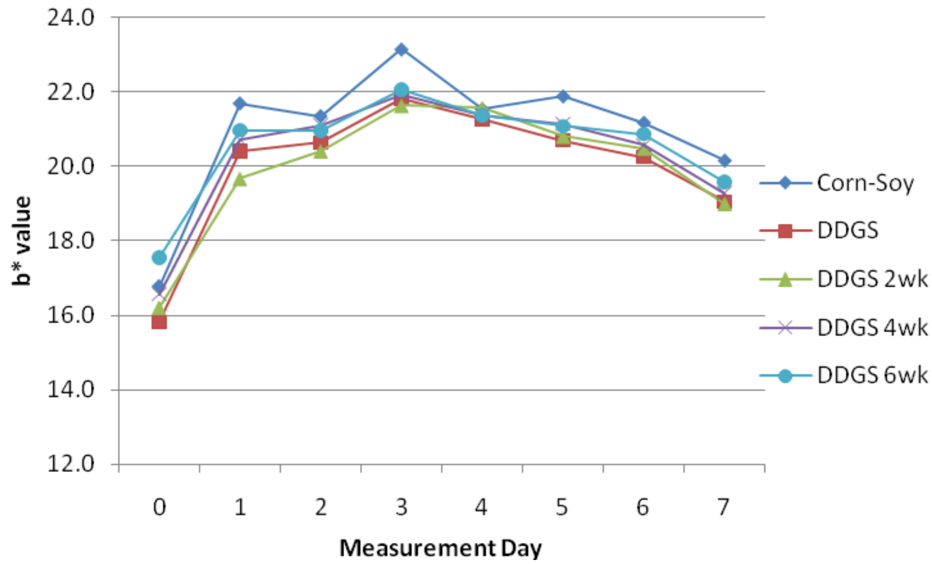

Figure 8. Effect of feeding a high level of DDGS (45%) and withdrawing DDGS on the b* value of loin chops over a 7 day period. Higher b* values mean less of a blue color and more of a yellow color. Corn-soybean meal vs. DDGS ($P < 0.05$) on days 0, 2, 3, 5, and 6. Linear ($P < 0.05$) effect of withdrawal time on day 0.

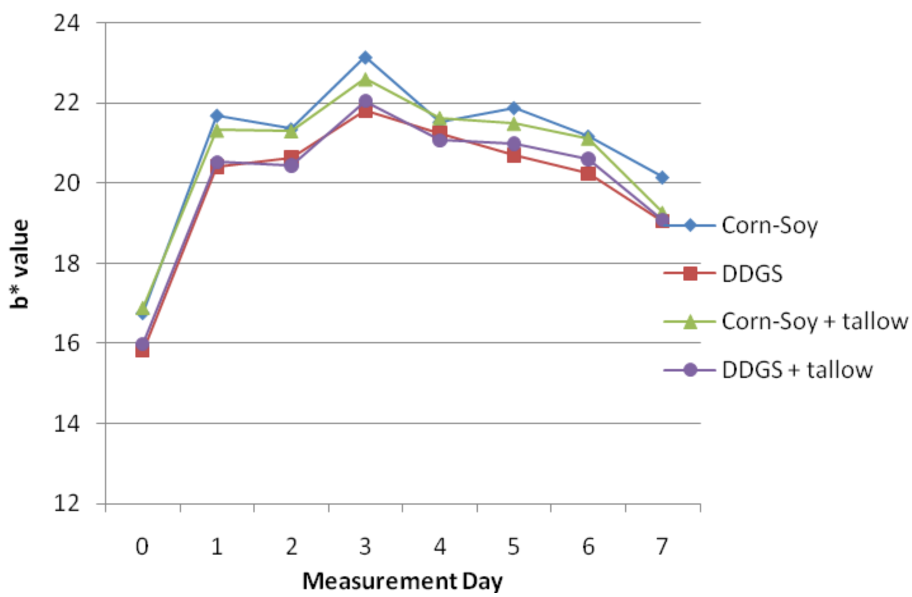

Figure 9. Effects of supplementing a hard fat (tallow) to a corn-soybean meal diet without and with a high level of DDGS on b* values of loin chops over a 7 day period. Higher b* values mean less of a blue color and more of a yellow color. Main effect of DDGS ($P < 0.05$) on days 0, 2, 3, 5, and 6.

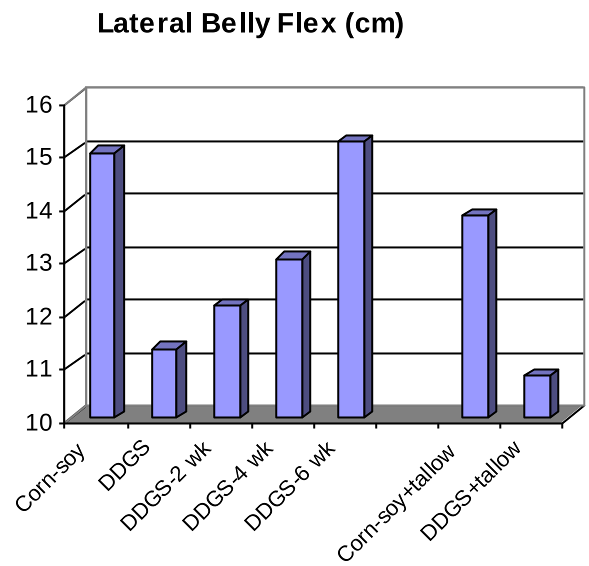

Figure 10. Lateral flex of bellies from pigs fed a corn-soybean meal control diet, a diet with 45% DDGS, three diets with DDGS withdrawn the final 2, 4, or 6 weeks of the finishing period, and the control and DDGS diets with 5% added tallow. The lower flex numbers represent a softer belly.

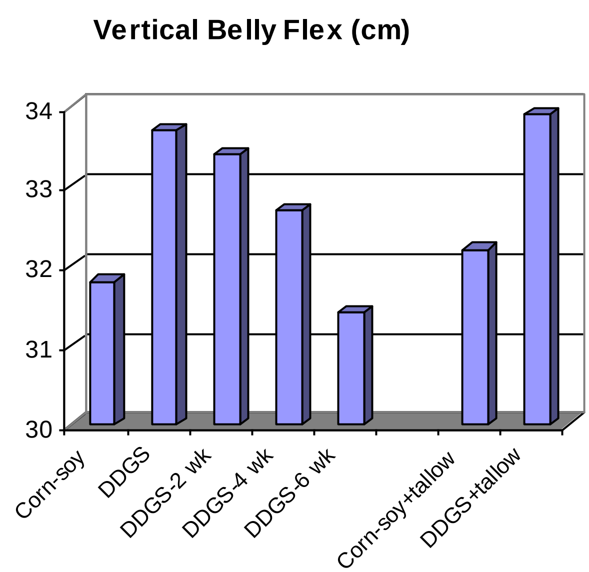

Figure 11. Vertical flex of bellies from pigs fed a corn-soybean meal control diet, a diet with 45% DDGS, three diets with DDGS withdrawn the final 2, 4, or 6 weeks of the finishing period, and the control and DDGS diets with 5% added tallow. The higher flex values represent a softer belly.

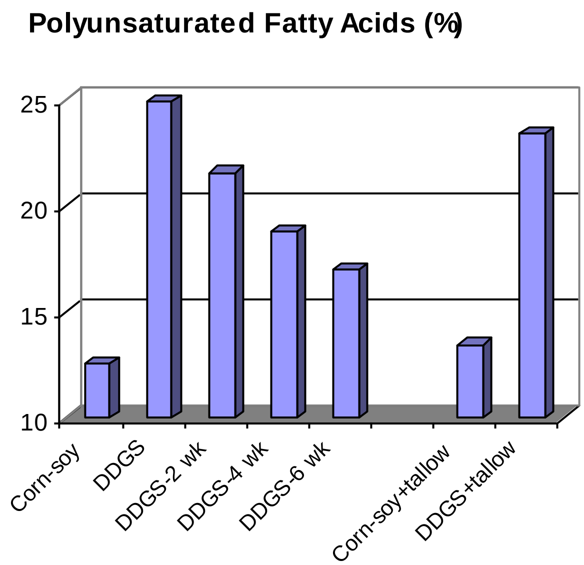

Figure 12. Polyunsaturated fatty acids in fat (mean of inner and outer backfat and belly fat) of pigs fed a corn-soybean meal control diet, a diet with 45% DDGS, three diets with DDGS withdrawn the final 2, 4, or 6 weeks of the finishing period, and the control and DDGS diets with 5% added tallow.

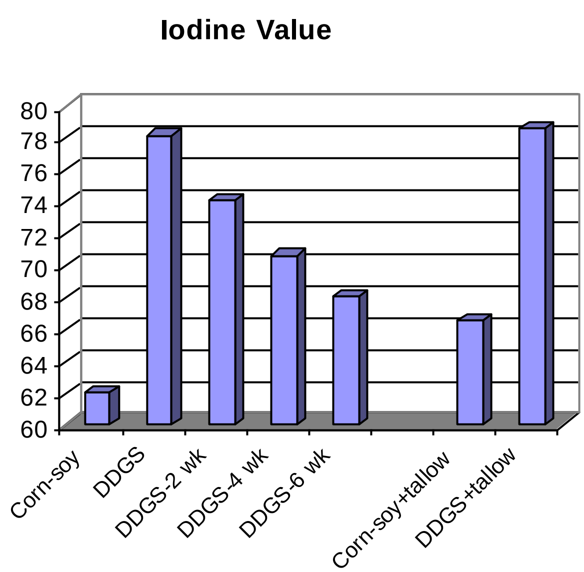

Figure 13. Iodine values of the fat (mean of inner and outer backfat and belly fat) of pigs fed a corn-soybean meal control diet, a diet with 45% DDGS, three diets with DDGS withdrawn the final 2, 4, or 6 weeks of the finishing period, and the control and DDGS diets with 5% added tallow.

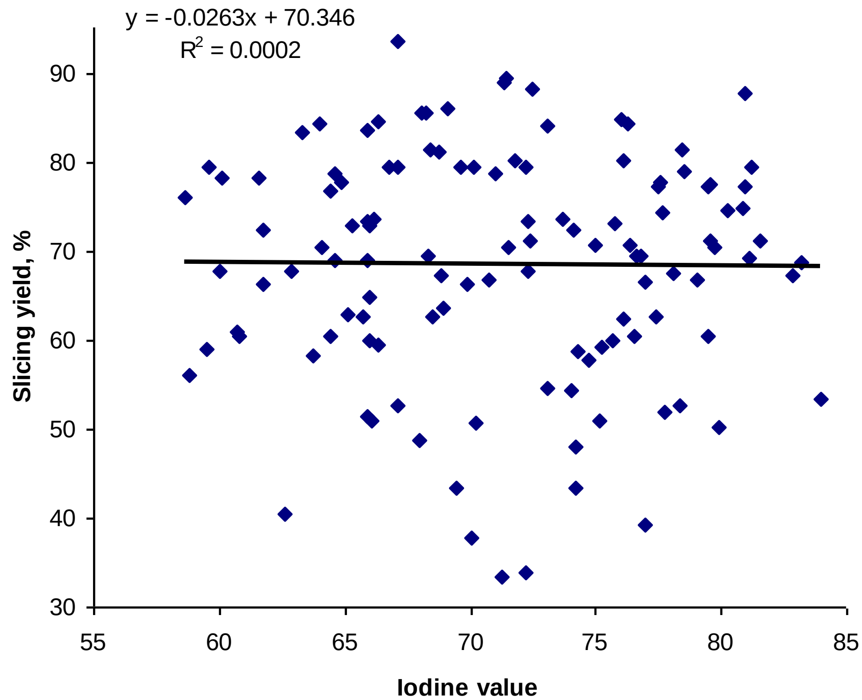

Figure 14. Relationship of iodine value (mean of inner and outer backfat and belly fat) and slicing yield of cured bellies. The data are from the 128 bellies in the study. A nearly flat regression line and a low R^2 indicates that there was no relationship between the two traits.