RESEARCH REPORT

ANIMAL SCIENCE

Title: Reducing feed cost by maximizing dietary byproduct feeding length prior to market - **NPB #12-167**

Investigator: Drs. Joel DeRouchey,

Institution: Kansas State University

Co-Investigators: Kyle Coble, Mike Tokach, Bob Goodband and Terry Houser

Date Submitted: November 19, 2013

Industry Summary:

The overriding objective is to improve the industry-wide lack of knowledge in utilizing high levels of by-products (DDGS and wheat middlings) in late finishing diets prior to marketing to further reduce feed cost. In order to accomplish this overall objective, two experiments were conducted to determine the optimum time period of dietary fiber reduction prior to marketing as determined by growth performance, carcass characteristics (primarily yield), digestive tract weights, carcass fat iodine value and economics.

These data did provide new information in that switching pigs fed a high fiber diet to a corn-soybean meal diet for as little as 5 days prior to slaughter will restored over half of the lost carcass yield. Further, switching to a corn-soybean meal based diet 15 days prior to slaughter fully restored carcass yield. In Exp. 2 while no statistical differences were found, numerical patterns to that of Exp. 1 were seen, where pigs changed to a corn-soybean meal diet for 9 days restored over half of the lost carcass yield, with 14 to 19 days of fiber diet withdrawal fully restoring carcass yield.

To help explain the change in yield, digestive track weights were measured in Exp. 1. First, when the large intestine was weighed full of digestive contents, the pigs fed the high fiber diet had 2.64 lb more of digestive contents remaining in the large intestine than that of pigs only fed the corn-soybean meal diet throughout the trial. After a 5 day withdrawal to the corn-soybean meal diet from the high fiber diet, full large intestine weight dropped by 2 lb. Secondly, and more minor influence, while not statistically different, the rinsed large intestine weighed 0.27 lb more from pigs fed the high fiber diet compared to the corn-soybean meal diet throughout finishing. Since both the weight of intestinal contents and the actual weight of the large intestine negatively influence carcass yield, both can help explain why pigs fed high fiber diets lave lower carcass yield then those fed a low fiber diet. From a packer prospective, feeding a high fiber diet until marketing increases the amount of waste generated and disposed of through either their own or multiple sewer systems.

For carcass fat quality, it was expected that pigs fed the high fiber diet would have softer carcass fat due to the increased level of unsaturated fat from the DDGS and wheat middlings in that diet. Our research did in fact

find this result. However, when evaluating the withdraw times of the high fiber to the corn-soybean meal diet, the iodine value of pigs did decrease (become more firm) in belly and backfat as the withdrawal days increased, but did not become fully restored to the corn-soybean meal diet fed throughout. This was not surprising as previous research has shown that once pigs are fed unsaturated fat in early and middle finishing, the withdraw days to a low unsaturated fat containing diet are more substantial to return to a baseline iodine value level.

From an economic prospective when measured as income over feed cost (IOCF = revenue/pig – feed cost/pig), in Exp. 1 a linear improvement in IOFC was reported as the days of withdrawal increased from the high to low fiber diet prior to marketing. The maximum return of IOCF was for pigs fed the 20 day withdrawal treatment at $27.76 per pig, which was $1.64 higher per pig than fed only the corn-soybean meal diet and $2.97 over that of pigs fed the high fiber diet until marketing. In Experiment 2, no statistical differences were found, but similar to Exp. 1, the maximum return on an IOCF basis was for pigs fed the 19 day withdrawal strategy at $28.88 per pig, which was $2.92/pig higher than pigs fed only the corn-soybean meal diet and $2.30 over pigs fed the high fiber diet until marketing.

Producer bottom line:

- Pigs fed the high-fiber, lower energy diet had poorer F/G, lower carcass yield and softer carcass fat compared with pigs fed the corn-soybean meal control diet.
- Withdrawing pigs from the high-fiber diet and switching them to a corn-soy control diet restored carcass yield when done for the last 15 to 20 d prior to harvest
- Pigs fed the high fiber diet had 2.64 lb more of digestive contents remaining in the large intestine than that of pigs only fed the corn-soybean meal diet throughout the trial. After a 5 day withdrawal to the corn-soybean meal diet from the high fiber diet, full large intestine weight dropped by 2 lb.
- Income over feed costs was maximized when finishing pigs were fed the high fiber, low energy diet until 20 days prior to marketing and switched to a corn-soybean meal diet.
- Carcass fatty acid composition and iodine value were impacted by diet type and with increasing withdrawal time of a high fiber diet containing DDGS and wheat middlings to a corn-soybean meal diet, but not back to the baseline level for pigs only fed the corn-soybean meal diet.

Dr. Joel DeRouchey
Kansas State University
Department of Animal Sciences and Industry
222 Weber Hall
Manhattan, KS 66506
785-532-2280
jderouch@ksu.edu

Kyle Coble
Kansas State University
Department of Animal Sciences and Industry
217 Weber Hall
Manhattan, KS 66506
785-532-1270
kcoble@ksu.edu

Keywords:

Carcass yield, Distiller dried grains with solubles, fiber, finishing pig, growth, wheat middlings

Scientific Abstract:

Two experiments were conducted to determine the timing of high-fiber ingredient removal from the diet prior to marketing to optimize growth performance, carcass characteristics (primarily yield), carcass fatty acid composition, and economics. In Exp. 1, a total of 288 pigs (PIC 327 × 1050; initially 84.7 lb) were used in an 88-d study. Two diet types, a corn-soybean meal control diet with low NDF (9.3%) and a high-fiber, high-NDF (19%) diet that contained 30% dried distillers grains with solubles (DDGS) and 19% wheat middlings (midds) were used throughout the study. Pens of pigs were randomly allotted to 1 of 6 dietary feeding strategies with 8 pigs per pen (4 barrows and 4 gilts) and 6 replications per treatment. The 6 feeding strategies consisted of the corn-soy control diet or high-fiber diet fed for the duration of the study, or the high-fiber diet fed until 20, 15, 10, or 5 d prior to slaughter after which the pigs were switched to the corn-soybean meal control diet. Overall (d 0 to 88), ADG was not affected by diet type or withdrawal strategy. Pigs fed the high-fiber diet continuously tended ($P < 0.07$) to have increased ADFI compared with pigs fed the control diet. This led to an increase ($P < 0.01$) in F/G for pigs fed the high-fiber diet for the entire study compared to pigs fed the control diet. The caloric efficiency of live weight gain of pigs fed the high-fiber diet continuously was worse ($P < 0.03$) compared with pigs fed the control diet throughout. Withdrawing the high-fiber diet and switching to the control diet did not influence growth performance. For carcass characteristics, percentage yield and backfat were reduced ($P < 0.01$), whereas loin depth and jowl iodine value increased ($P < 0.01$) in pigs fed the high-fiber diet continuously compared with those fed the corn-soybean meal control diet. As days of withdrawal from the high-fiber diet increased, percentage yield improved (linear; $P < 0.01$), whereas jowl iodine value decreased (linear; $P < 0.01$) and backfat increased (quadratic; $P < 0.04$). These data suggest that 15- to 20-d of removal from high-fiber diets prior to slaughter was optimal in terms of percentage carcass yield. The full pluck from pigs fed the high-fiber diet continuously tended to weigh more ($P < 0.10$) than from those fed the control diet. In addition, pigs continuously fed the high-fiber diet had heavier ($P < 0.01$) whole intestines, specifically full large intestines, than pigs fed the control. For pigs fed the high-fiber diet and then switched to the corn-soy control, whole intestine weight tended to decrease (linear; $P < 0.06$) and full large intestine weight decreased (linear; $P < 0.02$) as withdrawal time increased.

For Exp. 2, a total of 1,089 mixed-sex pigs (PIC 337 × 1050; initial BW 98.2 lb) were used in a 96-d study. The two diet types fed during the study were a corn-soybean meal control diet with low NDF (9.3%) and a high-fiber diet with high NDF (19%) that contained 30% dried distillers grains with solubles (DDGS) and 19% wheat middlings (midds). Pens of pigs were randomly allotted to 1 of 6 dietary feeding strategies with 25 to 27 pigs per pen and 7 replications per treatment. The six dietary strategies consisted of the corn-soybean meal control diet or high-fiber diet fed for the duration of the study, or the high-fiber diet fed until 24, 19, 14, or 9 d prior to harvest, at which time the pigs were switched to the corn-soybean meal control diet for the remainder of the study. Overall (d 0 to 96), pigs fed the high-fiber diet through the entire study compared with the corn-soy control diet had lower ($P < 0.01$) ADG and poorer F/G. This reduction in growth performance led to a trend for poorer ($P < 0.10$) caloric efficiency and lower ($P < 0.01$) final BW in pigs fed the high-fiber diet throughout compared to the control. For pigs fed the high-fiber diet then switched to the corn-soy control, ADG and ADFI were not different between withdrawal days, but F/G tended (linear; $P < 0.07$) to improve as withdrawal days increased from 0 to 24 d. Pigs fed the high-fiber diet throughout had a 9.5-lb lighter ($P < 0.01$) HCW compared to those fed the corn-soy control. Neither percentage yield using the farm live weight or plant live weight were significantly influenced by withdrawal days from the high-fiber diet; however, HCW increased linearly ($P < 0.05$) as withdrawal days increased. Backfat and loin depth both decreased ($P < 0.02$) in pigs fed the high-fiber diet throughout compared with those fed the corn–soybean meal diet. Loin depth increased, then decreased (quadratic; $P < 0.04$) as high-fiber diet withdrawal time increased. Total feed cost per pig and feed cost per lb of gain was lower ($P < 0.01$) for pigs fed the high-fiber diet until harvest, but carcass gain value per pig also decreased ($P < 0.01$) by $7.34. Total feed cost tended ($P < 0.10$) to increase and carcass gain value increased ($P < 0.05$) as high-fiber diet withdrawal time increased. Although no significant differences were observed in income over feed cost (IOFC) between treatments, switching pigs from the high-fiber diet to the corn-soybean meal diet at 14 to 19 d before market numerically increased IOFC by $1.42 to $2.30/pig over pigs fed the high-fiber diet continuously and $2.04 to 2.92/pig over pigs fed the corn-soybean meal diet throughout.

In summary, pigs fed the high-fiber diet had increased F/G, poorer caloric efficiency, and lower carcass yield compared with pigs fed the corn-soy control. Withdrawing pigs from the high-fiber diet and switching them to a corn-soy control diet did restore carcass yield when done for the last 15- to 20-d prior to harvest.

Introduction:

Including feed ingredient sources that are higher in fiber and lower in energy to partially replace a portion of the corn and soybean meal in diets has become a common practice. Reduced carcass yield is one negative effect of including high-fiber ingredients such as DDGS or wheat middlings. Research has reported (Asmus et al., 2011[1]) that changing pigs from a high-NDF diet (19% NDF; 30% DDGS and 19% wheat middlings) to a corn-soybean meal diet (9.3% NDF) approximately 20 d prior to marketing fully restored carcass yield; furthermore switching from a high- to low-NDF diet prior to market could reduce gut fill and intestinal weights. Although packers do not pay producers on a yield basis, feeding high-fiber diets do influence HCW, thus affecting producer revenue. More data are needed to determine the optimum time to switch finishing pigs from the high- to low-NDF diet to fully recover carcass yield loss associated with higher fiber diets.

Objectives:

1) Determine the optimum time period of dietary NDF reduction prior to marketing as determined by growth performance, carcass characteristics (primarily yield), carcass fat IV and economics.

    - In Exp. 1, a successful dietary model (19% NDF; 30% DDGS and 19% wheat middlings) already developed at Kansas State University will be first completed to answer the objective with a field validation study to be conducted in Exp. 2.

Materials & Methods: This section should include experimental design, methods and procedures used, number of animals, etc.

The K-State Institutional Animal Care and Use Committee approved the protocols used in these experiments. Experiment 1 was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. Experiment 2 was conducted at New Horizon Farms, Pipestone, MN.

Experiment 1.
A total of 288 pigs (PIC 327 × 1050; initially 84.7 lb) were used in an 88-d study. Pens of pigs were randomly allotted to 1 of 6 dietary feeding strategies with 8 pigs per pen (4 barrows and 4 gilts) and 6 replications per treatment. The 6 dietary strategies consisted of a corn-soy control diet (NDF = 9%) or high-fiber diet (NDF = 19%; 30% DDGS and 19% wheat middlings) fed for the duration of the study, or the high-fiber diet fed until 20, 15, 10, or 5 d prior to slaughter after which pigs were fed the corn-soy control diet. All diets were formulated on a standardized ileal digestible (SID) lysine basis and fed in 4 dietary phases (Tables 1 and 2). All diets were fed in meal form.

Composite samples of the DDGS and wheat middlings used in the diets were collected at the time of manufacturing and analyzed for DM, CP, fat, crude fiber, NDF, ADF, and ash (Table 3). Samples of the complete feed were obtained from each delivery for each diet type to measure bulk density (Table 4). In addition, samples of the DDGS, wheat middlings, and complete diets were analyzed for fatty acid concentrations (Table 5).

[1] Asmus, M.D. et al., Swine Day 2012, Report of Progress 1074, pp. 204–207.

Pens of pigs and feeders were weighed approximately every 3 wk to calculate ADG, ADFI, and F/G. When the pigs reached approximately 227 lb, pigs fed the high-fiber diet were realloted to withdrawal strategy, balancing by the d 0 and d 68 average pen weights. This was done to ensure that any measured criteria were not influenced by prior performance when the pigs were all fed the same diet. During the last 20 d of the experiment, all pens of pigs and feeders were weighed each time a treatment group switched diets, which was 20, 15, 10, and 5 d prior to slaughter. Prior to harvest, pigs were individually tattooed for identification purposes in the plant. On the final day of the study, pens of pigs and feeders were weighed and each pig was weighed individually to allow carcass yield to be calculated. The second-heaviest gilt in each pen (1 pig per pen, 6 pigs per treatment) was identified and transported to the K-State Meat Laboratory, and all other pigs were transported to Triumph Foods LLC (St. Joseph, MO) for processing and data collection. Carcass measurements taken at the commercial plant included HCW, backfat, loin depth, and percentage lean. Jowl fat samples were collected and analyzed by near-infrared spectroscopy (NIR) at the plant for iodine value (IV). Percentage yield was calculated by dividing HCW at the plant by live weight at the farm and multiplying by 100.

Gilts selected for harvest at K-State were blocked by treatment and randomly assigned to a slaughter order to equalize withdrawal time before slaughter. Immediately after evisceration, the entire pluck was weighed and individual organs (stomach, cecum, large intestine, small intestine, heart, liver, lungs, kidneys, spleen, and reproductive tract) were separated and weighed. The weights of the stomach, cecum, and large intestine were weighed full of intestinal contents, and weighed again after they were flushed with water and stripped of contents to determine an empty weight. During the harvest process, carcasses were split into two halves. At the end of the harvesting process, each pair of sides were moved onto a scale to record HCW and railed into a cooler for storage and further carcass measurements.

Carcass quality measurements were taken 24 h after slaughter on the right side of the carcass, which was ribbed at the 10th rib. Marbling and color scores were determined for the loin by using the Pork Quality Standards according to the American Meat Science Association (AMSA) and the National Pork Producers Council (NPPC). Ultimate pH of the loin was determined with a portable Hazard Analysis Critical Control Point (HACCP)–compliant pH meter designed for meat (model HI 99163; Hanna Instruments, Smithfield, RI). Fat samples from the jowl, belly, backfat, and ham collar were collected and analyzed for fatty acid. Jowl samples were taken from the lowest portion of the jowl when the carcass was hanging. Belly samples were taken from behind the 2nd teat on the teat line. Samples of the backfat were taken at the 10th rib on the outer edge of the loin. Lastly, ham collar samples were collected from the middle portion of the ham collar. All 3 layers of fat were used in the analysis.

Measurements of belly quality were also collected from bellies cut from the left side of each carcass. The weight, length, width, and height were recorded for each belly. A belly flop test was also performed on each belly to determine firmness. To measure belly flop, bellies were centered upon a fulcrum point and allowed to hang for 1 min, at which point the distance between the two ends were measured. This was completed with both the skin side up and skin side down.

At the conclusion of the study, an economic analysis was completed to determine the impact of withdrawing pigs from a high-fiber diet to the control diet prior to harvest. The total feed cost per pig was calculated by multiplying the ADFI by the feed cost per pound and the number of days in each respective period, then taking the sum of those values for each period. Cost per pound of gain was calculated by dividing the total feed cost per pig by the total pounds gained overall. Carcass gain value was calculated by multiplying the HCW by an assumed carcass value of $77.00/cwt and then subtracting initial pig cost, which was determined by multiplying the initial weight by 75% and the assumed carcass value of $77.00/cwt. To calculate income over feed cost (IOFC), total feed cost was subtracted from the value of the carcass gain.

Experiment 2.

A total of 1,089 mixed-sex pigs (PIC 337 × 1050; initial BW 98.2 lb) were used in a 96-d study.

Two diet types were fed consisting of a corn-soybean meal control diet with low NDF (9.3%) and a high-fiber diet with high NDF (19%) that contained 30% DDGS and 19% wheat midds. Diets were formulated on a standardized ileal digestible (SID) lysine basis and fed in meal form in 4 phases (Tables 1 and 2). Pens of pigs were randomly allotted to 1 of 6 dietary feeding strategies with 25 to 27 pigs per pen and 7 replications per treatment. The six dietary strategies consisted of the corn-soybean meal control diet or high-fiber diet fed for the duration of the study, or the high-fiber diet fed until 24, 19, 14, or 9 d prior to slaughter, at which time the pigs were switched to the corn-soybean meal control diet for the remainder of the study. The original design was to change pigs at d 20, 15, 10, and 5 prior to harvest; however, inclement weather led to a power outage at the processing plant and increased the original withdrawal schedule by 4 d.

Samples of the DDGS and midds used in the diets were collected at the time of manufacturing and a composite sample was analyzed. Analyses included DM, CP, ether extract (fat), CF, ADF, NDF, and ash. Samples of the complete feed were taken from the feeder at the beginning and end of each phase, and composite samples for each phase and diet type were made to determine bulk density.

Pens of pigs were weighed and feeder measurements were recorded on d 0, 14, 27, 64, 72, 77, 82, 87, and 96 to calculate ADG, ADFI, F/G, and ME caloric efficiency. On d 64, the 3 heaviest pigs in each pen were weighed and sold according to standard farm procedures. After removing those pigs, pens on the high-fiber diets were realloted to withdrawal time, balancing on d 0 and 64 average BW across treatments to ensure that prior performance did not bias the performance during the last phase when pigs were withdrawn from the high-fiber diet. During the high-fiber diet withdrawal period, all pens of pigs were weighed and feeder measurements were recorded each time a treatment group switched diets. Prior to marketing, the remaining pigs were individually tattooed with a pen ID number to allow for carcass measurements to be recorded on a pen basis. On d 96, final pen weights were taken, and pigs were transported to a commercial packing plant (JBS Swift and Company, Worthington, MN) for processing and carcass data collection. Carcass measurements taken at the plant included HCW, loin depth, backfat, and percentage lean. Also, percentage carcass yield was calculated by dividing the average pen HCW by average final live weight both at the farm and plant.

At the conclusion of the study, an economic analysis was completed to determine the financial impact of withdrawing pigs from a high-fiber diet to the control diet prior to harvest. The total feed cost per pig was calculated by multiplying the ADFI by the feed cost per pound and the number of days in each respective period, then taking the sum of those values for each period. Cost per pound of gain was calculated by dividing the total feed cost per pig by the total pounds gained overall. Carcass gain value was calculated by multiplying the HCW by an assumed carcass value of $77.00/cwt, then subtracting an initial pig cost, which was determined by multiplying the initial weight by 75% and the assumed carcass value of $77.00/cwt. To calculate IOFC, total feed cost was subtracted from the value of the carcass gain.

Statistical Analysis.
Data from both experiments were analyzed utilizing the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen serving as the experimental unit. Linear and quadratic contrasts were completed to determine the effects of withdrawing the high-fiber diet prior to slaughter, as well as a contrast between the corn-soy control and high-fiber diet fed throughout the entire study. Hot carcass weight served as a covariate for the analysis of loin depth, backfat, and percentage lean. Data are presented as least square means, and results were considered significant at $P \leq 0.05$ and tendencies between $P > 0.05$ and $P \leq 0.10$.

Results:

Experiment 1.

Chemical analysis of the DDGS and wheat middlings were similar to the nutrient values used for diet formulation (Table 3). As DDGS and wheat middlings were included in the diet, diet bulk density was reduced (Table 4). Fatty acid analysis of the wheat middlings, DDGS, and complete diets showed that the iodine value product (IVP) was lower in wheat middlings compared with DDGS (34.72 vs. 51.97). Also, because of the lower fat content, the corn-soy control diets had much lower IVP (15.7 to 21.3) than the high-fiber diet (20.6 to 43.9).

For growth performance from d 0 to 63, pigs fed the high-fiber diet for the entire study tended to have decreased ($P < 0.07$) ADG and worse ($P < 0.01$) F/G than pigs fed the corn-soybean meal control (Table 6).

From day d 63 to 88, pigs fed the high-fiber diet throughout tended to have greater ($P < 0.06$) ADG and ADFI ($P < 0.01$) compared with pigs fed the corn-soybean meal control diet. This resulted in no difference in F/G between the two treatments. For pigs withdrawn from the high-fiber diet and switched to the corn-soy control, there were no differences in ADG or F/G; however, ADFI increased then decreased (quadratic; $P < 0.05$) as days of fiber withdrawal prior to slaughter increased.

Overall (d 0 to 88), ADG was not affected by diet type or withdrawal strategy. Pigs fed the high-fiber diet continuously tended ($P < 0.07$) to have increased ADFI compared with pigs fed the control diet. This led to poorer ($P < 0.01$) F/G for pigs fed the high-fiber diet throughout compared with pigs fed the control diet. The caloric efficiency of pigs fed the high-fiber diet was worse ($P < 0.03$) compared with pigs fed the control diet, which suggest the energy content of the high-fiber diet was overestimated. Timing of the withdrawal of high-fiber ingredients prior to slaughter did not influence overall growth performance.

For carcass characteristics, percentage yield and backfat were reduced ($P < 0.01$), whereas percentage lean and jowl IV increased ($P < 0.01$) in pigs fed the high-fiber diet continuously compared with those fed the corn-soybean meal control diet (Table 7). As days withdrawn from the high-fiber diet increased, percentage yield improved (linear; $P < 0.01$; quadratic, $P < 0.03$), whereas jowl IV decreased (linear; $P < 0.01$) and backfat increased (quadratic; $P < 0.04$). These data suggest that 15 to 20 d of feeding a corn-soybean meal based diet prior to slaughter was optimal to recover percentage carcass yield when pigs were previously fed a high-fiber diet.

Pigs fed the high-fiber throughout tended ($P < 0.06$) to have increased belly width compared with those fed the control diet. In addition, belly firmness decreased ($P < 0.01$) when bellies were measured skin-up and skin-down for pigs fed the high-fiber diet continuously compared with pigs fed the control diet. Belly characteristics and firmness were not affected by withdrawal time.

Feed cost per pig, feed cost per pound of gain, and carcass gain value per pig all decreased ($P < 0.01$) in pigs fed the high-fiber diet throughout the study compared with those fed the control diet, but IOFC did not differ. Feed cost per pound of gain tended to respond in a quadratic ($P < 0.09$) manner as withdrawal time decreased, with the lowest feed cost per pound of gain for no withdrawal or 20 d of withdrawal. As a result of the improved carcass yield, IOFC tended to increase (linear; $P < 0.08$) as withdrawal time increased from 0 to 20 d. Pigs fed the high-fiber diet until 20 d prior to harvest had the highest IOFC at $27.76 per pig, or $1.64 over that of pigs fed the control.

Intestinal weights were analyzed on both a weight (Table 8) and percentage of BW (Table 9) basis. On a weight basis, the full pluck from pigs fed the high-fiber diet continuously tended to weigh more ($P < 0.10$) than plucks from pigs fed the control diet. Pigs fed the high-fiber diet continuously also had heavier ($P < 0.04$) whole intestines and full large intestines ($P < 0.01$) than pigs fed the control diet. This result suggests that more intestinal contents remained in the large intestine of the pigs fed the high-fiber diet than in the control-fed pigs. For pigs fed the high-fiber diet then switched to the control, whole intestine weight tended to decrease (linear; $P < 0.06$) and full large intestine weight decreased (linear; $P < 0.02$) as withdrawal time increased. With the exception of the lungs, which unexpectedly tended to increase (linear; $P < 0.08$) as withdrawal time increased, the rinsed weights of the organs did not differ in the various diet types or withdrawal strategies.

When expressed as a percentage of BW, the whole intestine tended ($P < 0.06$) to be a greater percentage of BW in pigs fed the high-fiber diet continuously compared with pigs fed the control diet. As the number of days pigs were withdrawn from the high-fiber diet increased, however, whole intestine as a percentage of BW decreased (linear; $P < 0.05$). The spleen occupied a lower ($P < 0.04$) percentage of BW in pigs fed the high-fiber throughout compared with the control. Similarly, the full large intestines of pigs fed the high-fiber diet also contributed a higher ($P < 0.01$) percentage of BW. The same effect existed for the full large intestine and spleen, because it contributed a lower (linear; $P < 0.05$) percentage of BW as days withdrawn from the high-fiber diet increased. The tendency for a quadratic response ($P < 0.06$) in full intestine weight when expressed as a percentage of BW indicates that much of the change in full intestine weight occurred in the first 5 d of withdrawal. Again, the lungs tended to increase (linear; $P < 0.09$) in weight as a percentage of BW as high-fiber diet withdrawal time increased.

Fatty acid analysis completed on the jowl, belly, backfat, and ham collar fat are reported in Tables 10, 11, 12, and 13, respectively. For pigs fed the high-fiber diet compared with the control diet, the concentration of polyunsaturated fatty acids (PUFA) was higher ($P < 0.01$) in jowl fat, partially because of the increase ($P < 0.01$) in linoleic (C18:2n-6) and α-linoleic (C18:3n-3) acid. Total *trans* fatty acids also increased ($P < 0.01$) in pigs fed the high-fiber diet throughout compared with pigs fed the corn-soy control. The PUFA:SFA (saturated fatty acid) ratio and IV also were higher ($P < 0.01$) in the jowl fat of pigs fed the high-fiber diet compared with the corn-soy control.

Fat from the belly of pigs fed the high-fiber diet had a lower ($P < 0.01$) percentage of MUFA (monounsaturated fatty acids) and higher ($P < 0.01$) percentage of PUFA compared with those fed the corn-soy diet. This was mainly due to the shift from lower ($P < 0.01$) amounts of oleic acid (C18:1 *cis*-9) and higher amounts of linoleic and α-linoleic acid in the belly fat of pigs fed the control diet compared with the high-fiber diet. The PUFA:SFA ratio and IV also were higher ($P < 0.01$) in the belly fat of pigs fed the high-fiber diet for the entire study.

Similar differences existed in the backfat and ham collar fat of pigs fed the high-fiber diet compared with the corn-coy control. The total concentration of PUFA, concentration of total *trans* fatty acids, PUFA:SFA ratio, and IV increased ($P < 0.01$) when pigs were fed the high-fiber diet compared with the corn-soybean meal control. In addition to those differences, the concentrations of eicosatrienoic acid (C20:3n-3), dihomo-γ-linoleic acid (C20:3n-6), and arachidonic acid (C20:4n-6) were also higher ($P < 0.04$) in pigs fed the high-fiber compared with the corn-soy control. The concentration of total *trans* fatty acids, however, were higher ($P < 0.01$) only in backfat of pigs fed the high-fiber compared with the corn-soy control.

For pigs withdrawn from the high-fiber diet and switched to the corn-soy control, fewer differences were observed in fatty acid concentration. The concentration of palmitoleic acid increased (linear; $P < 0.03$) in jowl fat as the number of days withdrawn from the high-fiber diet increased. The concentration of eicosatrienoic decreased (linear; $P < 0.01$) in belly fat as the number of days withdrawn from the high-fiber diet increased. Most differences existed in the backfat, where total concentration of PUFA, PUFA:SFA ratio, and IV decreased (quadratic; $P < 0.03$) with the increase in withdrawal time. The difference in total concentration of PUFA was due in part to the change (quadratic; $P < 0.03$) in concentrations of α-linoleic, linoleic acid, and arachidonic acid as withdrawal time increased. Dihomo-γ-linoleic acid concentration also decreased (quadratic; $P < 0.01$) as withdrawal time increased. Total concentration of PUFA in ham collar fat also increased (quadratic; $P < 0.05$) as withdrawal time increased, partially because of the increase in α-linoleic and arachidonic acid (quadratic; *P* <

0.04). The concentration of dihomo-γ-linoleic also increased (quadratic; $P < 0.02$) as withdrawal time increased from 0 to 20 d.

Table 1. Phase 1 and 2 diet composition (as-fed basis)[1]

	Phase 1		Phase 2	
Item	Control	High-fiber	Control	High-fiber
Ingredient, %				
Corn	73.71	34.88	78.93	39.99
Soybean meal , 46.5% CP	23.80	13.74	18.84	8.71
DDGS[2]	---	30.00	---	30.00
Wheat middlings	---	19.00	---	19.00
Monocalcium P, 21%	0.45	---	0.35	---
Limestone	1.05	1.30	1.00	1.28
Salt	0.35	0.35	0.35	0.35
Vitamin premix	0.15	0.15	0.13	0.13
Trace mineral premix	0.15	0.15	0.13	0.13
L-lysine HCl	0.17	0.31	0.15	0.29
DL-methionine	0.02	---	---	---
L-threonine	0.03	---	0.01	---
Phytase[3]	0.13	0.13	0.13	0.13
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standard ileal digestible (SID) amino acids, %				
Lysine	0.93	0.93	0.79	0.79
Isoleucine:lysine	69	72	70	74
Leucine:lysine	156	188	169	206
Methionine:lysine	30	34	30	37
Met & Cys:lysine	59	69	62	75
Threonine:lysine	63	66	63	69
Tryptophan:lysine	19	19	19	19
Valine:lysine	78	88	81	94
SID lysine:ME, g/Mcal	2.79	2.84	2.36	2.41
ME, kcal/lb	1,513	1,484	1,516	1,486
Total lysine, %	1.04	1.09	0.89	0.94
CP, %	17.5	20.8	15.6	18.9
Ca, %	0.59	0.58	0.53	0.56
P, %	0.47	0.58	0.42	0.56
Available P, %	0.28	0.39	0.26	0.39
Crude fiber, %	2.5	4.9	2.5	4.9
NDF, %	9.2	18.9	9.3	19.0
Diet cost, $/ton	319.56	290.51	306.67	278.94

[1] Phase 1 diets were fed from approximately 85 to 140 lb; Phase 2 diets were fed from 140 to 182 lb.
[2] Dried distillers grains with solubles.
[3] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 204.3 phytase units (FTU)/lb, with a release of 0.11% available P.

Table 2. Phase 3 and 4 diet composition (as-fed basis)[1]

	Phase 3		Phase 4	
Item	Control	High-fiber	Control	High-fiber
Ingredient, %				
Corn	82.65	43.56	84.97	45.79
Soybean meal, 46.5% CP	15.32	5.20	13.15	3.04
DDGS[2]	---	30.00	---	30.00
Wheat middlings	---	19.00	---	19.00
Monocalcium P, 21%	0.25	---	0.20	---
Limestone	0.98	1.29	0.93	1.28
Salt	0.35	0.35	0.35	0.35
Vitamin premix	0.10	0.10	0.08	0.08
Trace mineral premix	0.10	0.10	0.08	0.08
L-lysine HCl	0.14	0.28	0.13	0.27
Phytase[3]	0.13	0.13	0.13	0.13
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standard ileal digestible (SID) amino acids, %				
Lysine	0.69	0.69	0.63	0.63
Isoleucine:lysine	72	76	73	78
Leucine:lysine	181	224	191	238
Methionine:lysine	32	40	33	43
Met & Cys:lysine	66	81	69	86
Threonine:lysine	64	72	66	74
Tryptophan:lysine	19.0	19.0	19.0	19.0
Valine:lysine	85	99	87	103
SID lysine:ME, g/Mcal	2.06	2.10	1.88	1.92
ME, kcal/lb	1,520	1,487	1,522	1,488
Total lysine, %	0.78	0.83	0.72	0.77
CP, %	14.3	17.6	13.5	16.7
Ca, %	0.49	0.55	0.46	0.54
P, %	0.39	0.55	0.37	0.54
Available P, %	0.23	0.38	0.22	0.38
Crude fiber, %	2.5	4.9	2.5	4.9
NDF, %	9.3	19.0	9.3	19.0
Diet cost, $/ton	397.79	270.66	292.50	265.50

[1] Phase 2 diets were fed from approximately 182 to 228 lb; Phase 2 diets were fed from 228 to 277 lb.
[2] Dried distillers grains with solubles.
[3] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 204.3 phytase units (FTU)/lb, with a release of 0.11% available P.

Table 3. Chemical analysis of dried distillers grains with solubles (DDGS) and wheat middlings (midds) (as-fed basis)

Nutrient, %	DDGS	Midds
DM	91.45	90.22
CP	27.5 (27.2)[1]	15.0 (15.9)
Ether extract	8.0	3.7
Crude fiber	7.3 (7.7)	7.8 (7.0)
ADF	12.4 (9.9)	12.2 (10.7)
NDF	28.9 (25.3)	34 (35.6)
Ash	4.64	5.55

[1]Values in parentheses indicate those used in diet formulation.

Table 4. Bulk density of experimental diets (as-fed basis)[1,2]

Bulk density, lb/bu	Control	High-fiber
Phase 1	48.01	37.43
Phase 2	46.51	37.18
Phase 3	48.24	37.43
Phase 4	47.11	36.09

[1] Diet samples were collected from the truck before unloading during each phase.

[2] Phase 1 was fed from d 0 to 22; Phase 2 from d 22 to 42; Phase 3 from d 42 to 63; Phase 4 from d 63 to 88.

Table 5. Fatty acid analysis of ingredients and treatment diets during each phase[1,2]

			Phase 1		Phase 2		Phase 3		Phase 4	
Item	DDGS[3]	Midds[4]	Control	High-fiber	Control	High-fiber	Control	High-fiber	Control	High-fiber
Myristic acid (C14:0), %	0.07	0.14	0.04	0.09	0.07	0.08	0.12	0.07	0.03	0.08
Palmitic acid (C16:0), %	15.80	16.17	14.93	16.03	15.22	15.29	14.47	14.80	15.14	15.49
Palmitoleic acid (C16:1), %	0.22	0.15	0.03	0.13	0.11	0.15	0.11	0.14	0.03	0.16
Stearic acid (C18:0), %	2.52	1.37	2.88	2.41	2.79	2.30	2.34	2.16	2.47	2.10
Oleic acid (C18:1 *cis*-9), %	26.02	19.21	23.03	24.14	25.53	25.21	26.33	25.94	25.08	24.31
Linoleic acid (C18:2n-6), %	52.25	57.11	55.09	53.96	52.45	53.28	53.44	53.88	53.77	54.58
α-linoleic acid (C18:3n-3), %	1.50	4.36	2.87	2.52	2.69	2.36	2.13	2.03	2.51	2.30
Arachidic acid (C20:0), %	0.40	0.24	0.39	0.36	0.27	0.39	0.42	0.40	0.14	0.35
Gadoleic acid (C20:1), %	0.27	0.73	0.10	0.26	0.12	0.37	0.28	0.35	0.06	0.29
Other fatty acids, %	0.94	0.52	0.63	0.10	0.72	0.56	0.38	0.23	0.77	0.34
Total SFA,[5] %	18.92	18.08	18.24	18.90	18.42	18.17	17.35	17.51	17.78	18.09
Total MUFA,[6] %	26.52	20.09	23.17	24.53	25.76	25.73	26.71	26.44	25.16	24.77
Total PUFA,[7] %	1.50	4.36	2.87	2.52	2.69	2.36	2.13	2.03	2.51	2.30
UFA:SFA ratio[8]	1.48	1.35	1.43	1.43	1.55	1.55	1.66	1.63	1.56	1.50
PUFA:SFA ratio[9]	0.08	0.24	0.16	0.13	0.15	0.13	0.12	0.12	0.14	0.13
Analyzed dietary lipids, %	4.43	2.72	1.73	2.59	1.47	3.37	1.79	3.62	1.29	1.69
Iodine value,[10] g/100g	117.2	127.6	122.8	121.1	120.0	120.6	121.1	121.4	121.4	121.8
Analyzed IVP[11]	51.9	34.7	21.3	31.4	17.5	40.6	21.7	43.9	15.7	20.6

[1] Values represent the mean of composite samples that were analyzed in duplicate.
[2] All values are on a DM basis.
[3] Dried distillers grains with solubles.
[4] Wheat middlings.
[5] Total SFA = ([C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.
[6] Total MUFA = ([C14:1] + [C16:1] + [C18:1*cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]); brackets indicate concentration.
[7] Total PUFA = ([C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:1] + [C20:4n-6]); brackets indicate concentration.
[8] UFA:SFA = (total MUFA+PUFA)/ total SFA.
[9] PUFA:SFA = total PUFA/ total SFA.
[10] Calculated as IV = [C16:1] × 0.950 + [C18:1] × 0.860 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C20:4] × 3.201 + [C22:1] × 0.723 + [C22:5] × 3.697 + [C22:6] × 4.463; brackets indicate concentration.
[11] Iodine value product of dietary lipids calculated from analyzed fatty acid composition × % analyzed dietary lipids × 0.10.

Table 6. Effects of high-fiber withdrawal prior to market on growth performance of finishing pigs[1]

		High-fiber ingredient withdrawal prior to market, d						Probability, *P* <		
								Control	Duration	
Item	Control	20	15	10	5	0	SEM	vs. 0 withdrawal	Linear	Quadratic
Weight, lb										
d 0	84.3	84.5	84.7	84.9	84.5	85.1	2.38	0.82	0.89	0.99
d 63	231.5	226.7	227.0	226.9	227.0	226.9	3.82	0.40	0.97	0.97
d 88	277.8	275.4	277.7	276.0	277.4	277.0	4.25	0.90	0.83	0.90
d 0 to 63										
ADG, lb	2.34	2.26	2.26	2.26	2.25	2.25	0.033	0.07	---	---
ADFI, lb	6.08	6.09	6.18	6.21	6.20	6.17	0.099	0.53	---	---
F/G	2.60	2.70	2.74	2.75	2.75	2.74	0.024	0.01	---	---
d 63 to 88										
ADG, lb	1.85	1.91	2.03	1.97	2.01	2.00	0.055	0.06	0.33	0.48
ADFI, lb	6.32	6.74	7.13	6.99	7.27	6.97	0.124	0.01	0.14	0.05
F/G	3.42	3.54	3.51	3.57	3.62	3.49	0.069	0.52	0.99	0.41
d 0 to 88										
ADG, lb	2.20	2.16	2.19	2.18	2.19	2.18	0.030	0.61	0.71	0.65
ADFI, lb	6.15	6.27	6.45	6.43	6.50	6.40	0.094	0.07	0.33	0.20
F/G	2.79	2.91	2.94	2.96	2.98	2.93	0.026	0.01	0.27	0.15
Caloric efficiency[2]										
ME	4,237	4,343	4,390	4,406	4,430	4,361	38.3	0.03	0.54	0.13

[1] A total of 280 pigs (PIC 327 × 1050, initial BW= 84.7 lb) were used in an 88-d study with 8 pigs per pen and 6 replications per treatment fed either a corn-soy control (9.3% NDF) or a high-fiber (19.0% NDF) diet.

[2] Caloric efficiency is expressed as kcal/lb of live weight gain.

Table 7. Effects of high-fiber withdrawal prior to market in finishing pigs on carcass characteristics and economics

		High-fiber ingredient withdrawal prior to market, d						Probability, $P <$		
								Control	Duration	
Item	Control	20	15	10	5	0	SEM	vs. 0 withdrawal	Linear	Quadratic
Carcass characteristics										
HCW, lb	203.6	200.3	201.6	200.9	200.2	196.5	3.10	0.11	0.37	0.40
Yield,[2] %	72.69	72.50	72.51	72.24	72.03	71.15	0.204	0.01	0.01	0.03
Backfat,[3] in	0.79	0.68	0.70	0.71	0.69	0.64	0.021	0.01	0.18	0.04
Loin depth,[3] in	2.33	2.36	2.36	2.28	2.37	2.28	0.036	0.36	0.22	0.90
Lean,[3] %	52.62	53.66	53.31	53.03	53.67	53.66	0.268	0.01	0.68	0.12
Jowl iodine value[4]	66.8	72.6	73.3	73.2	73.8	74.5	0.350	0.01	0.01	0.65
Marbling[5]	1.50	1.33	1.30	1.25	1.08	1.25	0.153	0.26	0.44	0.63
Color[5]	2.25	2.17	2.00	2.42	1.67	2.17	0.202	0.77	0.61	0.83
Ultimate pH[5]	5.49	5.51	5.52	5.48	5.48	5.50	0.030	0.67	0.60	0.59
Belly characteristics[5]										
Weight, lb	10.90	11.13	11.45	10.91	11.43	11.68	0.474	0.26	0.48	0.62
Length, in	23.55	23.06	23.57	22.43	23.38	23.79	0.363	0.61	0.24	0.14
Width, in	8.93	9.29	9.20	9.24	9.16	9.57	0.253	0.06	0.48	0.32
Height, in	1.51	1.51	1.53	1.48	1.53	1.44	0.066	0.40	0.49	0.59
Belly Firmness[6]										
Skin-up, in	5.16	2.78	2.98	3.50	3.23	3.01	0.627	0.01	0.70	0.46
Skin-down, in	7.61	4.38	4.11	4.84	4.15	4.13	0.772	0.01	0.84	0.73
Economics, $/pig										
Feed cost	81.97	77.70	79.56	78.88	79.23	77.35	1.169	0.01	0.79	0.15
Feed cost/ lb gain	0.423	0.409	0.412	0.412	0.412	0.403	0.004	0.01	0.32	0.09
Carcass gain value[7]	108.10	105.46	106.31	105.64	105.36	102.14	1.479	0.01	0.12	0.17
IOFC[8]	26.12	27.76	26.76	26.77	26.13	24.79	1.129	0.41	0.08	0.76

[1] A total of 280 pigs (PIC 327 × 1050, initial BW= 84.7 lb) were used in an 88-d study with 8 pigs per pen and 6 replications per treatment fed either a corn-soy control (9.3% NDF) or a high-fiber (19.0% NDF) diet.
[2] Carcass characteristics were adjusted by using HCW as a covariate.
[3] Percentage yield was calculated by dividing HCW by live weight obtained at the farm before transport to the packing plant.
[4] Iodine value was measured on the jowl of the carcass at the plant.
[5] The second-heaviest gilt was selected to represent the pen.
[6] Values represent the distance from each end of the belly when centered upon a fulcrum point.
[7] Carcass gain value is calculated as $77.00/cwt of final carcass wt. minus (initial weight x 75% assumed yield x $77.00/cwt).
[8] Income over feed cost = revenue/pig – feed cost/pig.

Table 8. Effects of high-fiber withdrawal prior to market on finishing pig intestinal and organ weights, lb[1]

		High-fiber ingredient withdrawal prior to market, d						Probability, $P <$		
								Control	Duration	
Item, lb	Control	20	15	10	5	0	SEM	vs. 0 withdrawal	Linear	Quadratic
Full pluck	29.58	29.49	31.83	31.08	30.96	32.53	1.230	0.10	0.19	0.85
Whole intestine	19.45	18.93	21.17	20.21	20.41	22.25	0.935	0.04	0.06	0.92
Stomach										
Full	2.69	2.48	2.45	2.93	2.63	2.86	0.238	0.62	0.23	0.78
Rinsed	1.98	2.01	2.05	2.05	2.12	2.15	0.109	0.27	0.32	0.90
Cecum										
Full	1.62	1.58	1.97	1.88	1.89	2.03	0.178	0.11	0.16	0.58
Rinsed	0.68	0.62	0.72	0.63	0.71	0.68	0.036	1.00	0.30	0.57
Large intestine										
Full	6.39	6.52	7.51	6.38	7.04	9.03	0.569	0.01	0.02	0.09
Rinsed	3.94	3.85	4.42	3.94	4.09	4.21	0.191	0.33	0.53	0.70
Small intestine										
Rinsed	7.13	6.58	7.53	7.18	7.04	6.71	0.347	0.40	0.84	0.08
Heart	1.03	1.03	1.04	1.08	1.09	1.05	0.075	0.88	0.72	0.69
Lungs	2.38	2.58	2.47	2.59	2.18	2.36	0.129	0.89	0.08	0.92
Liver	4.10	4.36	4.48	4.53	4.43	4.20	0.199	0.73	0.56	0.27
Kidneys	0.84	0.94	0.99	0.99	0.88	0.97	0.061	0.16	0.77	0.86
Spleen	0.58	0.58	0.49	0.58	0.48	0.46	0.050	0.11	0.11	0.87
Reproductive tract	1.06	1.03	1.14	1.08	1.41	1.01	0.138	0.80	0.62	0.25

[1]The second-heaviest gilt was selected to represent the pen (6 pigs/treatment).

Table 9. Effects of high-fiber withdrawal prior to market on finishing pig intestinal and organ weights, % of live weight[1]

		High-fiber ingredient withdrawal prior to market, d						Probability, $P <$		
								Control	Duration	
Item,[2] %	Control	20	15	10	5	0	SEM	vs. 0 withdrawal	Linear	Quadratic
Full pluck	10.95	10.76	11.44	11.46	11.14	11.75	0.378	0.15	0.18	0.74
Whole intestine	7.20	6.92	7.61	7.46	7.33	8.04	0.295	0.06	0.05	0.97
Stomach										
Full	0.99	0.90	0.89	1.09	0.94	1.03	0.086	0.74	0.25	0.68
Rinsed	0.73	0.73	0.74	0.76	0.76	0.78	0.035	0.38	0.31	0.94
Cecum										
Full	0.60	0.58	0.71	0.69	0.67	0.74	0.062	0.14	0.17	0.55
Rinsed	0.25	0.23	0.26	0.23	0.25	0.25	0.013	0.71	0.37	0.56
Large intestine										
Full	2.37	2.38	2.69	2.34	2.53	3.26	0.188	0.01	0.01	0.06
Rinsed	1.47	1.41	1.59	1.45	1.47	1.52	0.059	0.53	0.57	0.64
Small intestine										
Rinsed	2.64	2.41	2.71	2.66	2.54	2.42	0.136	0.27	0.75	0.09
Heart	0.38	0.38	0.37	0.40	0.40	0.38	0.030	0.94	0.72	0.62
Lungs	0.88	0.95	0.89	0.96	0.79	0.85	0.051	0.69	0.09	0.98
Liver	1.52	1.59	1.61	1.67	1.60	1.52	0.059	0.98	0.42	0.14
Kidneys	0.31	0.34	0.35	0.36	0.32	0.35	0.018	0.15	0.66	0.84
Spleen	0.21	0.21	0.18	0.21	0.17	0.17	0.015	0.04	0.05	0.87
Reproductive tract	0.39	0.38	0.41	0.39	0.52	0.37	0.053	0.74	0.62	0.25

[1] The second-heaviest gilt was selected to represent the pen (6 pigs/treatment).
[2] All values are expressed as a percent of final live weight (ex. (full pluck/final live weight) × 100).

Table 10. Effects of high-fiber withdrawal prior to market on jowl fatty acid analysis[1,2]

		High-fiber ingredient withdrawal prior to market, d						Probability, $P <$		
								Control	Duration	
Item	Control	20	15	10	5	0	SEM	vs. 0 withdrawal	Linear	Quadratic
Myristic acid (C14:0). %	1.30	1.41	1.38	1.34	1.33	1.28	0.071	0.84	0.15	0.98
Myristoleic acid (C14:1), %	0.02	0.03	0.02	0.02	0.02	0.02	0.003	0.73	0.12	0.15
Palmitic acid (C16:0), %	23.30	22.23	24.99	22.25	22.33	21.98	1.203	0.40	0.37	0.42
Palmitoleic acid (C16:1), %	3.29	3.67	3.41	3.12	3.32	2.94	0.234	0.26	0.03	0.75
Stearic acid (C18:0), %	10.26	8.67	11.00	9.55	9.18	9.57	0.735	0.47	0.99	0.27
Oleic acid (C18:1 *cis*-9), %	48.56	44.95	37.91	44.55	44.58	43.72	2.979	0.22	0.63	0.58
Linoleic acid (C18:2n-6), %	9.95	15.33	16.91	15.25	15.50	16.45	0.998	0.01	0.78	0.85
α-linoleic acid (C18:3n-3), %	0.44	0.60	0.63	0.57	0.59	0.61	0.041	0.01	0.87	0.68
γ-linoleic acid (C18:3n-6), %	0.15	0.13	0.14	0.13	0.14	0.15	0.017	0.89	0.37	0.89
Conjugated Linoleic acid (*c*9, *t*11), %	0.09	0.11	0.12	0.11	0.12	0.11	0.011	0.20	0.98	0.94
Arachidic acid (C20:0), %	0.20	0.18	0.19	0.19	0.19	0.18	0.012	0.22	0.95	0.35
Gadoleic acid (C20:1), %	0.88	0.78	0.99	0.93	0.84	0.90	0.069	0.83	0.71	0.18
Eicosadienoic acid (C20:2), %	0.06	0.14	0.24	0.06	0.05	0.06	0.077	1.00	0.14	0.96
Eicosatrienoic acid (C20:3n-3), %	0.07	0.08	0.09	0.09	0.08	0.09	0.010	0.08	0.50	0.83
Dihomo-γ-linoleic acid (C20:3n-6), %	0.08	0.11	0.11	0.11	0.10	0.11	0.010	0.03	0.96	0.49
Arachidonic acid (C20:4n-6), %	0.21	0.27	0.31	0.25	0.25	0.27	0.022	0.06	0.37	0.81
Other fatty acids, %	0.69	0.68	0.82	0.72	0.69	0.79	0.063	0.22	0.63	0.99
Total SFA,[3] %	35.06	32.49	37.56	33.34	33.03	33.01	1.916	0.41	0.54	0.35
Total MUFA,[4] %	52.75	49.42	42.32	48.62	48.75	47.58	2.871	0.17	0.75	0.57
Total PUFA,[5] %	10.81	16.47	18.22	16.26	16.54	17.53	1.049	0.01	0.88	0.84
Total *trans* fatty acids,[6] %	0.59	0.73	0.76	0.70	0.73	0.76	0.049	0.01	0.87	0.70
UFA:SFA ratio[7]	1.82	2.04	1.74	1.96	1.98	1.97	0.117	0.31	0.76	0.35
PUFA:SFA ratio[8]	0.31	0.51	0.49	0.49	0.50	0.53	0.022	0.01	0.34	0.13
Iodine value,[9] g/100g	65.0	72.1	68.9	71.1	71.7	72.4	1.143	0.01	0.30	0.12

[1] The second-heaviest gilt in each pen was selected to represent the pen (6 pigs/treatment).

[2] All values are on a DM basis.

[3] Total SFA = ([C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.

[4] Total MUFA = ([C14:1] + [C16:1] + [C18:1*cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]); brackets indicate concentration.

[5] Total PUFA = ([C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:1] + [C20:4n-6]); brackets indicate concentration.

[6] Total *trans* fatty acids = ([C18:1trans] + [C18:2trans] + [C18:3trans]); brackets indicate concentration.

[7] UFA:SFA = (total MUFA+PUFA)/ total SFA.

[8] PUFA:SFA = total PUFA/ total SFA.

[9] Calculated as IV = [C16:1] × 0.950 + [C18:1] × 0.860 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C20:4] × 3.201 + [C22:1] × 0.723 + [C22:5] × 3.697 + [C22:6] × 4.463; brackets indicate concentration.

Table 11. Effects of high-fiber withdrawal prior to market on belly fatty acid analysis[1,2]

		High-fiber ingredient withdrawal prior to market, d						Probability, $P <$		
								Control	Duration	
Item	Control	20	15	10	5	0	SEM	vs. 0 withdrawal	Linear	Quadratic
Myristic acid (C14:0). %	1.30	1.41	1.23	1.39	1.38	1.33	0.043	0.65	0.83	0.53
Myristoleic acid (C14:1), %	0.02	0.02	0.02	0.02	0.03	0.02	0.004	0.66	0.41	0.53
Palmitic acid (C16:0), %	24.70	24.74	23.69	23.78	24.03	23.48	0.471	0.05	0.12	0.48
Palmitoleic acid (C16:1), %	3.41	3.33	3.07	2.95	3.28	3.10	0.164	0.15	0.60	0.29
Stearic acid (C18:0), %	11.46	11.14	11.06	11.01	10.56	10.33	0.544	0.12	0.19	0.71
Oleic acid (C18:1 *cis*-9), %	49.03	43.92	46.47	42.95	43.87	43.91	1.302	0.01	0.49	0.90
Linoleic acid (C18:2n-6), %	7.16	12.42	11.32	14.41	13.53	14.27	1.345	0.01	0.14	0.95
α-linoleic acid (C18:3n-3), %	0.31	0.47	0.42	0.54	0.51	0.53	0.058	0.01	0.22	0.97
γ-linoleic acid (C18:3n-6), %	0.11	0.04	0.06	0.08	0.09	0.08	0.027	0.44	0.17	0.44
Conjugated Linoleic acid (*c*9, *t*11), %	0.085	0.089	0.070	0.084	0.093	0.078	0.014	0.72	0.99	0.95
Arachidic acid (C20:0), %	0.21	0.19	0.16	0.19	0.16	0.18	0.012	0.07	0.53	0.46
Gadoleic acid (C20:1), %	0.84	0.69	0.82	0.79	0.76	0.83	0.066	0.90	0.26	0.65
Eicosadienoic acid (C20:2), %	0.28	0.21	0.24	0.20	0.23	0.22	0.075	0.52	0.99	0.96
Eicosatrienoic acid (C20:3n-3), %	0.03	0.02	0.03	0.06	0.05	0.06	0.012	0.06	0.01	0.38
Dihomo-γ-linoleic acid (C20:3n-6), %	0.05	0.09	0.06	0.09	0.08	0.09	0.014	0.03	0.47	0.52
Arachidonic acid (C20:4n-6), %	0.20	0.25	0.26	0.26	0.26	0.28	0.016	0.01	0.37	0.93
Other fatty acids, %	0.52	0.56	0.55	0.65	0.60	0.65	0.064	0.14	0.23	0.88
Total SFA,[3] %	37.66	37.48	36.14	36.37	36.12	35.31	0.927	0.06	0.12	0.86
Total MUFA,[4] %	53.30	47.96	50.39	46.71	47.94	47.86	1.447	0.01	0.53	0.98
Total PUFA,[5] %	8.06	13.39	12.30	15.49	14.62	15.38	1.386	0.01	0.13	0.94
Total *trans* fatty acids,[6] %	0.42	0.51	0.49	0.61	0.60	0.61	0.075	0.06	0.15	0.76
UFA:SFA ratio[7]	1.64	1.64	1.75	1.72	1.73	1.80	0.068	0.08	0.15	0.87
PUFA:SFA ratio[8]	0.21	0.36	0.34	0.43	0.40	0.44	0.042	0.01	0.09	0.95
Iodine value,[9] g/100g	60.2	65.1	65.2	67.8	67.3	68.6	1.682	0.01	0.08	0.91

[1] The second-heaviest gilt in each pen was selected to represent the pen (6 pigs/treatment).
[2] All values are on a DM basis.
[3] Total SFA = ([C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.
[4] Total MUFA = ([C14:1] + [C16:1] + [C18:1*cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]); brackets indicate concentration.
[5] Total PUFA = ([C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:1] + [C20:4n-6]); brackets indicate concentration.
[6] Total *trans* fatty acids = ([C18:1trans] + [C18:2trans] + [C18:3trans]); brackets indicate concentration.
[7] UFA:SFA = (total MUFA+PUFA)/total SFA.
[8] PUFA:SFA = total PUFA/total SFA.
[9] Calculated as IV = [C16:1] × 0.950 + [C18:1] × 0.860 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C20:4] × 3.201 + [C22:1] × 0.723 + [C22:5] × 3.697 + [C22:6] × 4.463; brackets indicate concentration.

Table 12. Effects of high-fiber withdrawal prior to market on backfat fatty acid analysis[1,2]

		High-fiber ingredient withdrawal prior to market, d						Probability, $P <$		
								Control	Duration	
Item	Control	20	15	10	5	0	SEM	vs. 0 withdrawal	Linear	Quadratic
Myristic acid (C14:0). %	1.23	1.40	1.18	1.30	1.27	1.23	0.061	0.99	0.22	0.34
Myristoleic acid (C14:1), %	0.01	0.02	0.01	0.01	0.01	0.01	0.002	0.51	0.54	0.84
Palmitic acid (C16:0), %	24.42	20.46	23.46	24.38	23.61	22.70	1.61	0.42	0.33	0.10
Palmitoleic acid (C16:1), %	2.75	2.66	2.30	2.36	2.50	2.35	0.139	0.04	0.31	0.30
Stearic acid (C18:0), %	13.64	13.40	13.44	10.81	12.27	11.88	0.998	0.18	0.16	0.36
Oleic acid (C18:1 *cis*-9), %	44.07	41.35	41.41	41.19	39.40	39.03	1.171	0.01	0.06	0.55
Linoleic acid (C18:2n-6), %	10.76	17.17	14.75	16.26	17.36	18.95	0.796	0.01	0.01	0.01
α-linoleic acid (C18:3n-3), %	0.43	0.64	0.53	0.57	0.63	0.66	0.035	0.01	0.16	0.02
γ-linoleic acid (C18:3n-6), %	0.13	0.12	0.13	0.13	0.12	0.11	0.013	0.41	0.48	0.45
Conjugated Linoleic acid (*c*9, *t*11), %	0.07	0.08	0.09	0.09	0.09	0.10	0.007	0.02	0.11	0.82
Arachidic acid (C20:0), %	0.25	0.25	0.24	0.24	0.24	0.22	0.019	0.16	0.28	0.84
Gadoleic acid (C20:1), %	0.77	0.72	0.81	0.87	0.75	0.78	0.054	0.86	0.64	0.11
Eicosadienoic acid (C20:2), %	0.05	0.04	0.04	0.04	0.04	0.04	0.008	0.50	0.98	0.72
Eicosatrienoic acid (C20:3n-3), %	0.05	0.07	0.06	0.08	0.08	0.08	0.006	0.01	0.03	0.44
Dihomo-γ-linoleic acid (C20:3n-6), %	0.08	0.10	0.08	0.10	0.10	0.11	0.004	0.01	0.08	0.01
Arachidonic acid (C20:4n-6), %	0.19	0.25	0.22	0.22	0.21	0.26	0.018	0.01	0.93	0.03
Other fatty acids, %	0.65	0.67	0.64	0.65	0.67	0.73	0.060	0.34	0.43	0.40
Total SFA,[3] %	39.55	35.51	38.32	36.74	37.39	36.03	1.447	0.07	0.98	0.23
Total MUFA,[4] %	47.60	44.75	44.53	44.43	42.67	42.18	1.290	0.01	0.07	0.62
Total PUFA,[5] %	11.56	18.22	15.67	17.22	18.35	20.02	0.843	0.01	0.02	0.01
Total *trans* fatty acids,[6] %	0.56	0.76	0.65	0.70	0.75	0.78	0.040	0.01	0.31	0.06
UFA:SFA ratio[7]	1.50	1.88	1.58	1.70	1.64	1.73	0.145	0.23	0.59	0.23
PUFA:SFA ratio[8]	0.29	0.54	0.41	0.47	0.49	0.56	0.045	0.01	0.40	0.03
Iodine value,[9] g/100g	61.8	71.2	66.4	69.0	69.5	72.1	1.716	0.01	0.33	0.04

[1] The second-heaviest gilt in each pen was selected to represent the pen (6 pigs/treatment).
[2] All values are on a DM basis.
[3] Total SFA = ([C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.
[4] Total MUFA = ([C14:1] + [C16:1] + [C18:1*cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]); brackets indicate concentration.
[5] Total PUFA = ([C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:1] + [C20:4n-6]); brackets indicate concentration.
[6] Total *trans* fatty acids = ([C18:1trans] + [C18:2trans] + [C18:3trans]); brackets indicate concentration.
[7] UFA:SFA = (total MUFA+PUFA)/ total SFA.
[8] PUFA:SFA = total PUFA/ total SFA.
[9] Calculated as IV = [C16:1] × 0.950 + [C18:1] × 0.860 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C20:4] × 3.201 + [C22:1] × 0.723 + [C22:5] × 3.697 + [C22:6] × 4.463; brackets indicate concentration.

Table 13. Effects of high-fiber withdrawal prior to market on ham collar fatty acid analysis[1,2]

								Probability, $P <$		
		High-fiber ingredient withdrawal prior to market, d						Control	Duration	
Item	Control	20	15	10	5	0	SEM	vs. 0 withdrawal	Linear	Quadratic
Myristic acid (C14:0). %	1.36	1.44	1.26	1.38	1.39	1.35	0.096	0.94	0.86	0.63
Myristoleic acid (C14:1), %	0.01	0.01	0.01	0.02	0.01	0.01	0.003	0.96	0.48	0.36
Palmitic acid (C16:0), %	23.87	25.56	22.19	22.99	22.80	22.69	1.173	0.44	0.14	0.18
Palmitoleic acid (C16:1), %	3.41	3.47	2.95	3.05	3.28	2.79	0.191	0.02	0.07	0.79
Stearic acid (C18:0), %	11.13	11.57	10.31	10.30	9.81	10.60	0.767	0.59	0.28	0.18
Oleic acid (C18:1 *cis*-9), %	46.38	35.89	43.22	42.69	42.25	40.50	2.882	0.13	0.33	0.08
Linoleic acid (C18:2n-6), %	10.45	18.12	16.26	15.69	16.61	17.71	1.081	0.01	0.89	0.06
α-linoleic acid (C18:3n-3), %	0.48	0.73	0.64	0.60	0.67	0.69	0.047	0.01	0.73	0.04
γ-linoleic acid (C18:3n-6), %	0.15	0.11	0.13	0.13	0.13	0.13	0.016	0.29	0.46	0.52
Conjugated Linoleic acid (*c*9, *t*11), %	0.09	0.10	0.11	0.09	0.11	0.09	0.012	0.91	0.46	0.80
Arachidic acid (C20:0), %	0.22	0.21	0.18	0.19	0.20	0.19	0.013	0.10	0.51	0.59
Gadoleic acid (C20:1), %	0.81	0.76	0.79	0.89	0.81	1.03	0.110	0.13	0.09	0.57
Eicosadienoic acid (C20:2), %	0.10	0.08	0.06	0.14	0.06	0.17	0.045	0.29	0.17	0.57
Eicosatrienoic acid (C20:3n-3), %	0.07	0.10	0.08	0.09	0.08	0.09	0.008	0.04	0.78	0.13
Dihomo-γ-linoleic acid (C20:3n-6), %	0.09	0.12	0.11	0.10	0.11	0.12	0.007	0.01	0.90	0.02
Arachidonic acid (C20:4n-6), %	0.24	0.33	0.30	0.26	0.28	0.31	0.020	0.01	0.33	0.02
Other fatty acids, %	0.71	0.76	0.75	0.71	0.72	0.81	0.074	0.32	0.77	0.35
Total SFA,[3] %	36.58	38.78	33.95	34.87	34.20	34.83	1.939	0.49	0.19	0.17
Total MUFA,[4] %	50.61	40.13	46.97	46.64	46.35	44.34	2.816	0.09	0.35	0.08
Total PUFA,[5] %	11.43	19.37	17.38	16.82	17.75	19.01	1.138	0.01	0.92	0.05
Total *trans* fatty acids,[6] %	0.63	0.84	0.76	0.73	0.79	0.82	0.052	0.01	0.94	0.09
UFA:SFA ratio[7]	1.70	1.65	1.90	1.83	1.88	1.82	0.105	0.36	0.28	0.18
PUFA:SFA ratio[8]	0.31	0.51	0.51	0.48	0.52	0.55	0.028	0.01	0.30	0.23
Iodine value,[9] g/100g	64.3	69.4	71.7	70.2	71.8	72.1	1.349	0.01	0.17	0.84

[1] The second-heaviest gilt in each pen was selected to represent the pen (6 pigs/treatment).
[2] All values are on a DM basis.
[3] Total SFA = ([C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.
[4] Total MUFA = ([C14:1] + [C16:1] + [C18:1*cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]); brackets indicate concentration.
[5] Total PUFA = ([C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:1] + [C20:4n-6]); brackets indicate concentration.
[6] Total *trans* fatty acids = ([C18:1trans] + [C18:2trans] + [C18:3trans]); brackets indicate concentration.
[7] UFA:SFA = (total MUFA+PUFA)/ total SFA.
[8] PUFA:SFA = total PUFA/ total SFA.
[9] Calculated as IV = [C16:1] × 0.950 + [C18:1] × 0.860 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C20:4] × 3.201 + [C22:1] × 0.723 + [C22:5] × 3.697 + [C22:6] × 4.463; brackets indicate concentration.

Experiment 2.

Proximate analysis completed on the DDGS and midds demonstrated that the nutrient values used for diet formulation were similar to the analyzed values (Table 16). As expected, diet bulk density showed that as DDGS and midds were included in the diet, bulk density was reduced (Table 17).

From day d 0 to 64, pigs fed the high-fiber diet throughout the entire study had decreased ($P < 0.02$) ADG and ADFI, as well as poorer ($P < 0.02$) F/G compared with pigs fed the corn-soy control; consequently, the high-fiber pigs weighed approximately 8 lb less than those fed the corn-soy control diet on d 64 (Table 18).

From d 64 to 96, there was no difference in ADG or ADFI between pigs fed the high-fiber or corn-soy diets throughout the study; however, F/G was worse ($P < 0.03$), and final BW was lower ($P < 0.01$) for pigs fed the high-fiber diet throughout compared with the corn-soy diet. There were no differences in ADG, ADFI, F/G, or final BW for pigs fed the high-fiber diet with different withdrawal days. The lack of significant differences may have been influenced by the daily weighing of pens the last 4 d of the experiment as we anticipated shipment each of those days, but the inclement weather prevented us from doing so. All treatments would have been influenced similarly during this time, but repeated weighing seems to have increased variation.

Overall (d 0 to 96), pigs continuously fed the high-fiber diet compared with the corn-soy control diet had lower ($P < 0.01$) ADG and poorer F/G, but ADFI was not affected. This reduction in growth performance led to decreased ($P < 0.01$) final BW and a tendency for poorer ($P < 0.10$) caloric efficiency for pigs fed the high-fiber diet throughout compared to the control. For pigs initially fed the high-fiber diet and then switched to the corn-soybean meal control, ADG and ADFI were not different between withdrawal days; however, F/G tended (linear; $P < 0.07$) to improve as withdrawal days increased from 0 to 24 d, with the pigs withdrawn 19 and 24 days prior to harvest being the most efficient. Final BW and caloric efficiency were unaffected by withdrawal days.

For carcass characteristics, pigs fed the high-fiber diet throughout had a 9.5-lb lighter ($P < 0.01$) HCW compared with pigs fed the corn-soy control (Table 19). Percentage yield was unaffected by dietary treatment, but daily weighing of pigs the last 4 d of the study may have reduced the potential to find a difference. Nevertheless, pigs withdrawn from the high-fiber diet had heavier HCW (linear; $P < 0.05$) as withdrawal days increased. Backfat and loin depth were both reduced ($P < 0.02$) in pigs continuously fed the high-fiber diet. Loin depth increased (quadratic; $P < 0.04$) as withdrawal time increased.

Total feed cost per pig and feed cost per lb of gain were lower ($P < 0.01$) for pigs fed the high-fiber diet until harvest. The value of the carcass gain was reduced ($P < 0.01$) by $7.34 in pigs fed the high-fiber diets throughout the entire study. Total feed cost tended ($P < 0.10$) to increase and carcass gain value increased ($P < 0.05$) as withdrawal time increased. Although we observed no significant differences in IOFC between treatments, switching pigs from the high-fiber diet to the corn-soybean meal diet at 15 to 19 d before market numerically increased IOFC by $1.42 to $2.30/pig over pigs continuously fed the high-fiber diet and $2.04 to 2.92/pig over pigs fed the corn-soybean meal diet throughout.

In summary, feeding diets higher in fiber has been and will continue to be a viable option to producers and nutritionist to decrease feed cost and reduce cost of gain. However, this practice is also associated with the consequences of reduced yield and HCW. These data indicate that much of the benefit in lower feed cost from feeding high-fiber diets can be captured while minimizing the loss of carcass value by switching pigs to a lower fiber, higher energy diet for 15 to 19 d prior to market.

Table 14. Phase 1 and 2 diet composition (as-fed basis)[1]

	Phase 1		Phase 2	
Item	Control	High-fiber	Control	High-fiber
Ingredient, %				
Corn	73.15	34.18	76.85	37.83
Soybean meal , 46.5% CP	24.55	14.68	20.97	11.10
DDGS[2]	---	30.00	---	30.00
Wheat middlings	---	19.00	---	19.00
Monocalcium P, 21%	0.60	---	0.55	---
Limestone	0.95	1.25	0.93	1.20
Salt	0.35	0.35	0.35	0.35
Vitamin and trace mineral premix[3]	0.10	0.10	0.10	0.10
L-lysine sulfate[4]	0.27	0.44	0.25	0.42
L-threonine	0.02	---	0.01	---
MHA[5]	0.01	---	---	---
Phytase[6]	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standard ileal digestible (SID) amino acids, %				
Lysine	0.95	0.95	0.85	0.85
Isoleucine:lysine	69	74	70	75
Leucine:lysine	155	189	163	202
Methionine:lysine	28	35	29	37
Met & Cys:lysine	58	66	60	70
Threonine:lysine	62	65	62	67
Tryptophan:lysine	19.0	19.0	19.0	19.0
Valine:lysine	78	90	80	93
SID lysine:ME, g/Mcal	2.84	2.90	2.54	2.59
ME, kcal/lb	1,517	1,486	1,518	1,488
Total lysine, %	1.07	1.13	0.96	1.02
CP, %	17.8	21.3	16.5	19.9
Ca, %	0.58	0.58	0.55	0.55
P, %	0.50	0.55	0.48	0.54
Available P, %	0.26	0.31	0.25	0.31
Crude fiber, %	2.6	5.3	3.3	5.1
NDF, %	9.2	20.5	9.2	20.5
Diet cost, $/ton	280.23	262.08	271.16	253.93

[1] Phase 1 diets were fed from approximately 98 to 127 lb; Phase 2 diets were fed from 127 to 175 lb.
[2] Dried distillers grains with solubles.
[3] Provided 2,043 IU/lb vitamin A, 318 IU/lb vitamin D, 11 IU/lb vitamin E, 1.4 ppm vitamin K, 3 ppm vitamin B_2, 18 ppm niacin, 12 ppm pant. acid, 40 ppm Mn, 100 ppm Zn, 90 ppm Fe, 10 ppm Cu, 0.3 ppm Se, and 0.5 ppm I to the complete diet.
[4] L-lysine sulfate provided by Biolys (Evonik Corporation, Kennesaw, GA).
[5] Methionine source (Novus International, St. Charles, MO).
[6] Optiphos 2000 (Enzyvia LLC, Sheridan, IN) provided 227 phytase units (FTU)/lb, with a release of 0.07% available P.

Table 15. Phase 3 and 4 diet composition (as-fed basis)[1]

	Phase 3		Phase 4	
Item	Control	High-fiber	Control	High-fiber
Ingredient, %				
Corn	80.16	41.17	83.10	43.99
Soybean meal, 46.5% CP	17.78	7.82	14.90	5.04
DDGS[2]	---	30.00	---	30.00
Wheat middlings	---	19.00	---	19.00
Monocalcium P, 21%	0.45	---	0.40	---
Limestone	0.95	1.18	0.95	1.15
Salt	0.35	0.35	0.35	0.35
Vitamin and trace mineral premix[3]	0.08	0.08	0.08	0.08
L-lysine sulfate[4]	0.23	0.40	0.21	0.38
L-threonine	---	---	0.01	---
Phytase[5]	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standard ileal digestible (SID) amino acids, %				
Lysine	0.76	0.76	0.68	0.68
Isoleucine:lysine	71	77	72	79
Leucine:lysine	172	216	183	231
Methionine:lysine	30	39	32	42
Met & Cys:lysine	63	75	66	80
Threonine:lysine	63	69	65	71
Tryptophan:lysine	19.0	19.0	19.0	19.0
Valine:lysine	83	97	85	102
SID lysine:ME, g/Mcal	2.27	2.32	2.03	2.07
ME, kcal/lb	1,520	1,489	1,522	1,490
Total lysine, %	0.86	0.92	0.77	0.84
CP, %	15.3	18.7	14.2	17.6
Ca, %	0.53	0.53	0.51	0.51
P, %	0.44	0.53	0.42	0.52
Available P, %	0.22	0.31	0.21	0.30
Crude fiber, %	2.5	5.2	2.4	5.2
NDF, %	9.3	20.6	9.3	20.6
Diet cost, $/ton	262.88	246.12	256.16	239.17

[1] Phase 3 diets were fed from approximately 175 to 225 lb; Phase 4 diets were fed from 225 to 286 lb.
[2] Dried distillers grains with solubles.
[3] Provided 2,043 IU/lb vitamin A, 318 IU/lb vitamin D, 11 IU/lb vitamin E, 1.4 ppm vitamin K, 3 ppm vitamin B_2, 18 ppm niacin, 12 ppm pant. acid, 40 ppm Mn, 100 ppm Zn, 90 ppm Fe, 10 ppm Cu, 0.3 ppm Se, and 0.5 ppm I to the complete diet.
[4] L-lysine sulfate provided by Biolys (Evonik Corporation, Kennesaw, GA).
[5] Optiphos 2000 (Enzyvia LLC, Sheridan, IN) provided 227 phytase units (FTU)/lb, with a release of 0.07% available P.

Table 16. Chemical analysis of dried distillers grains with solubles (DDGS) and wheat middlings (midds); (as-fed basis)

Nutrient, %	DDGS	Midds
DM	90.35	90.72
CP	29.4 (27.3)[1]	15.5 (15.9)
Ether extract (fat)	11.2	4.4
Crude fiber	7.4 (8.9)	8.4 (7.0)
ADF	9.1 (12.0)	11.9 (10.7)
NDF	22.4 (30.4)	34.6 (35.6)
Ash	3.89	4.97

[1] Values in parentheses indicate those used in diet formulation.

Table 17. Bulk density of experimental diets (as-fed basis)[1,2]

Bulk density, lb/bu	Control	High-fiber
Phase 1	45.6	38.2
Phase 2	45.4	40.0
Phase 3	44.3	35.6
Phase 4	44.8	35.1

[1] Diet samples were collected at the beginning and end of each phase from the feeder.

[2] Phase 1 was fed from d 0 to 14 ; Phase 2 from d 14 to 37; Phase 3 from d 37 to 64; Phase 4 from d 64 to 96.

Table 18. Effects of high-fiber withdrawal prior to market on growth performance of finishing pigs[1]

Item	Control	High-fiber withdrawal prior to market, d					SEM	Probability, P <		
								Control	Duration	
		24	19	14	9	0		vs. 0 withdrawal	Linear	Quadratic
Weight, lb										
d 0	98.2	98.0	98.1	98.2	98.2	98.2	2.07	1.00	0.88	0.92
d 64	232.1	224.3	223.8	224.2	224.0	224.5	3.24	0.01	0.85	0.73
d 96	292.0	285.1	285.5	284.7	283.0	282.7	3.48	0.01	0.23	0.80
d 0 to 64										
ADG, lb	2.09	1.97	1.96	1.97	1.97	1.97	0.028	0.01	--	--
ADFI, lb	5.63	5.38	5.38	5.40	5.41	5.48	0.069	0.02	--	--
F/G	2.69	2.73	2.74	2.75	2.75	2.79	0.028	0.02	--	--
d 64 to 96										
ADG, lb	1.88	1.91	1.90	1.91	1.82	1.86	0.041	0.72	0.20	0.98
ADFI, lb	6.24	6.54	6.44	6.55	6.43	6.46	0.122	0.19	0.61	0.95
F/G	3.31	3.43	3.40	3.43	3.53	3.48	0.059	0.03	0.17	0.85
d 0 to 96										
ADG, lb	2.03	1.95	1.94	1.95	1.92	1.94	0.021	0.01	0.28	0.79
ADFI, lb	5.82	5.74	5.71	5.76	5.73	5.79	0.077	0.68	0.53	0.66
F/G	2.87	2.94	2.94	2.95	2.98	2.99	0.024	0.01	0.07	0.79
Caloric efficiency[2]										
ME	4,364	4,401	4,400	4,411	4,452	4,448	35.12	0.10	0.19	0.86

[1] A total of 1,089 pigs (PIC 337 × 1050, initial BW= 98.2 lb) were used in a 96-d study with 7 replications per treatment.
[2] Caloric efficiency is expressed as ME kcal/lb gain.

Table 19. Effects of high-fiber withdrawal prior to market of finishing pigs on carcass characteristics and economics

		High-fiber withdrawal prior to market, d						Probability, $P <$		
Item	Control	24	19	14	9	0	SEM	Control vs. 0 withdrawal	Linear	Quadratic
Carcass characteristics										
HCW, lb	218.5	211.2	212.9	212.2	210.6	209.0	2.00	0.01	0.05	0.08
Yield,[2] %										
Farm	74.85	74.10	74.62	74.54	74.43	73.93	0.496	0.19	0.73	0.27
Plant	75.35	74.28	74.59	75.14	74.95	74.52	0.705	0.39	0.69	0.37
Backfat,[3] in	0.704	0.659	0.673	0.654	0.641	0.645	0.016	0.02	0.21	0.79
Loin depth,[3] in	2.619	2.556	2.582	2.580	2.595	2.515	0.030	0.02	0.39	0.04
Lean,[3] %	55.90	56.45	56.32	56.57	56.87	56.55	0.296	0.14	0.39	0.75
Economics, $/pig										
Feed cost	85.58	79.30	78.36	78.65	77.69	77.62	1.061	0.01	0.10	0.86
Feed cost/lb gain	0.440	0.423	0.420	0.420	0.422	0.418	0.003	0.01	0.34	0.95
Carcass gain value[4]	111.54	105.95	107.25	106.65	105.44	104.20	1.543	0.01	0.05	0.08
IOFC[5]	25.96	26.64	28.88	28.00	27.75	26.58	1.261	0.71	0.73	0.17

[1] A total of 1,089 pigs (PIC 337 × 1050, initial BW= 98.2 lb) were used in a 96-d study with 7 replications per treatment.
[2] Percentage yield was calculated by dividing HCW by pen live weight obtained at the farm before transport to the packing plant as well as the pen live weight obtained at the plant.
[3] Carcass characteristics were adjusted by using HCW as a covariate.
[4] Carcass gain value is calculated as $77.00/cwt of final carcass wt. minus (initial weight x 75% assumed yield x $77.00/cwt).
[5] Income over feed cost = carcass gain value – feed cost.

Discussion:

Results from both experiments validated that feeding a high fiber, lower energy diet (utilizing DDGS and wheat middlings) resulted in poorer daily gains and feed efficiency and reduced carcass yield. While these are not a new findings with this diet type, the aim of the research was to determine how to overcome this loss in performance and final carcass weight by implementing a withdraw strategy of feeding the high fiber, low energy diet first, then switching to a corn-soybean meal diet prior to marketing.

These data did provide new information in that switching pigs fed a high fiber diet to a corn-soybean meal diet for as little as 5 days prior to slaughter will restored over half of the lost carcass yield. Further, switching pigs to a corn-soybean meal based diet 15 days prior to slaughter fully restored carcass yield. Unfortunately in Exp. 2 when marketing was delayed due to the packing plant closure, the marketing day did not exactly match that of Exp. 1 as planned. Also, we feel due to increased human to pig contact by weighing pigs daily for the 5 days prior to shipment an anticipation of plant opening, as well as the extreme cold weather conditions, additional stress on the pigs created more variation then is typically seen for this research site in final weights and carcass characteristics. Thus, while no statistical differences were found, numerical patterns to that of Exp. 1 were seen, where pigs changed to a corn-soybean meal diet for 9 days restored over half of the lost carcass yield, with 14 to 19 days of fiber diet withdrawal fully restoring carcass yield.

To help explain the change in yield, digestive track weights were measured in Exp. 1. First, when the large intestine was weighed full of digestive contents, the pigs fed the high fiber diet had 2.64 lb more of digestive contents remaining in the large intestine than that of pigs only fed the corn-soybean meal diet throughout the trial. After a 5 day withdrawal to the corn-soybean meal diet from the high fiber diet, full large intestine weight dropped by 2 lb. Secondly, and more minor influence, while not statistically different, the rinsed large intestine weighed 0.27 lb more from pigs fed the high fiber diet compared to the corn-soybean meal diet throughout finishing. This confirms other research that reported the digestive track is heavier in pigs fed high fiber compared to a low fiber diet. Since both the weight of intestinal contents and the actual weight of the large intestine negatively influence carcass yield, both can help explain why pigs fed high fiber diets lave lower carcass yield then those fed a low fiber diet. From a packer prospective, feeding a high fiber diet until marketing increases the amount of waste generated and disposed of through either their own or multiple sewer systems.

For carcass fat quality, it was expected that pigs fed the high fiber diet would have softer carcass fat due to the increased level of unsaturated fat from the DDGS and wheat middlings in that diet. Our research did in fact find this result. However, when evaluating the withdraw times of the high fiber to the corn-soybean meal diet, the iodine value of pigs did decrease in belly and backfat as the withdrawal days increased, but did not become fully restored to the corn-soybean meal diet fed throughout. This was not surprising as previous research has shown that once pigs are fed unsaturated fat in early and middle finishing, the withdraw days to a low unsaturated fat containing diet are more substantial to return to a baseline iodine value level.

From an economic prospective when measured as income over feed cost (IOCF = revenue/pig – feed cost/pig), in Exp. 1 a linear improvement in IOFC was reported as the days of withdrawal increased from the high to low fiber diet prior to marketing. The maximum return of IOCF was for pigs fed the 20 day withdrawal treatment at $27.76 per pig, which was $1.64 higher per pig than fed only the corn-soybean meal diet and $2.97 over that of pigs fed the high fiber diet until marketing. In Experiment 2, no statistical differences were found, but similar to Exp. 1, the maximum return on an IOCF basis was for pigs fed the 19 day withdrawal strategy at $28.88 per pig, which was $2.92/pig higher than pigs fed only the corn-soybean meal diet and $2.30 over pigs fed the high fiber diet until marketing.

In conclusion, pigs fed the high-fiber diet had poorer F/G, lower carcass yield and softer carcass fat compared with pigs fed the corn-soybean meal control diet. Withdrawing pigs from the high-fiber diet and switching them to a corn-soy control diet restored carcass yield when done for the last 15 to 20 d prior to harvest and provided for maximum return on an IOFC basis. Withdrawal of high fiber ingredients less than 20 d prior to slaughter, however, did not have a measurable impact on carcass fatty acid composition.