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Effects of replacing soybean meal with pea chips and distillers dried grains with solubles in diets fed to growing-finishing pigs on growth performance, carcass quality, and pork palatability[1]

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ABSTRACT

Twenty-four growing pigs, 12 barrows and 12 gilts (initial BW of 23.18 ± 0.38 kg), were allotted to 1 of 3 dietary treatments. The control treatment group received corn–soybean meal diets during the growing, early finishing, and late finishing periods. The second treatment group received diets in which 50% of the soybean meal (SBM) was replaced with pea chips and distillers dried grains with solubles (DDGS), and the third treatment group received diets in which 100% of the SBM was replaced with pea chips and DDGS. Pigs were slaughtered at the end of the experiment; standard carcass measurements were collected for longissimus dorsi, gluteus medius, and serratus ventralis muscles. Pork chops were evaluated for tenderness, juiciness, and flavor. In the overall performance, ADFI was reduced (linear, $P = 0.02$) with pea chips and DDGS inclusion. End live weight ($P = 0.04$), HCW ($P = 0.02$), and belly firmness ($P = 0.04$) were also linearly reduced as field peas and DDGS replaced SBM in the diets. In the gluteus medius, 24-h pH was increased (quadratic, $P = 0.05$) when pigs were fed the 50% pea chips and DDGS inclusion diet. Percent cook loss, shear force, tenderness, and juiciness of the pork chops were not altered ($P > 0.24$); however, flavor decreased (linear, $P = 0.05$) as pea chips and DDGS replaced SBM in the diets. Diets containing the combination of pea chips and DDGS need to be less expensive than corn-SBM diets to be economical to feed to growing and finishing pigs.

Key words: carcass composition, distillers dried grains with solubles, palatability, pea chips, pork quality

INTRODUCTION

Distillers dried grains with solubles (**DDGS**) is produced in the Midwest, and effects on growth performance of growing-finishing pigs fed DDGS have been reported (Whitney et al., 2006; Linneen et al., 2008). Effects of DDGS on carcass quality and pork palatability have also been reported (Widmer et al., 2008). Based on this research, it has been concluded that DDGS may be included in diets fed to growing-finishing pigs at concentrations of up to 20% (Stein and Shurson, 2009).

North Dakota is the largest producer of field peas in the United States (NASS, 2011). A large proportion of field peas are split and used for

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human consumption, but during this process, a coproduct called pea chips is produced (Newman et al., 2011). Pea chips consist of peas that are crushed during the splitting process, and pea chips may replace all of the soybean meal (**SBM**) in diets fed to growing-finishing pigs without negatively influencing pig performance (Newman et al., 2011).

Pea protein has a relatively high concentration of lysine and a low concentration of methionine and cysteine (Stein et al., 2004), whereas the protein in DDGS has a relatively low concentration of lysine but a high concentration of methionine and cysteine. The 2 protein sources, therefore, may complement each other, but there are no reports on the effects of feeding a combination of field peas and DDGS to growing-finishing pigs. The objective of this experiment was, therefore, to evaluate the effects of replacing SBM with a combination of field peas and DDGS in diets fed to growing-finishing pigs on pig growth performance, carcass quality, and the palatability of pork chops.

MATERIALS AND METHODS

Animal Growth Performance

The protocol for this experiment was reviewed and approved by the Institutional Animal Care and Use Committee at North Dakota State University. Twenty-four growing pigs, 12 gilts and 12 barrows, were used in the experiment. Pigs (initial BW of 23.18 ± 0.38 kg) were the offspring of Hampshire × Duroc boars that were mated to Landrace × Yorkshire females. Pigs were blocked by sex and initial BW and randomly assigned to 1 of 3 treatment groups with 8 replicate pigs, 4 gilts and 4 barrows, per treatment group. Pigs were housed individually in 0.89 × 1.47 m pens in an environmentally controlled group with a 14-h-light and 10-h-dark cycle. Pens had fully slatted plastic floors, a one-hole feeder, and a nipple drinker.

Table 1. Analyzed nutrient composition of pea chips, distillers dried grains with solubles (DDGS), corn, and soybean meal (as-fed basis)

Nutrient, %	Pea chips	DDGS	Corn	Soybean meal
DM	91.20	91.27	89.21	90.61
CP	23.40	28.12	8.51	49.57
ADF	6.77	10.39	1.53	3.62
NDF	7.23	34.80	7.31	7.33
Calcium	0.10	—	0.01	0.44
Phosphorus	0.43	1.09	0.32	0.66
Indispensable amino acids				
Arginine	2.08	1.15	0.36	3.30
Histidine	0.57	0.79	0.22	1.21
Isoleucine	0.92	0.96	0.28	2.05
Leucine	1.63	3.03	0.91	3.55
Lysine	1.67	0.96	0.25	2.93
Methionine	0.25	0.54	0.17	0.65
Phenylalanine	1.08	1.16	0.37	3.31
Threonine	0.88	0.99	0.26	1.77
Tryptophan	0.20	0.20	0.07	0.71
Valine	1.04	1.34	0.38	2.15
Dispensable amino acids				
Alanine	1.02	1.89	0.56	1.97
Asparagine	2.67	1.64	0.50	5.21
Cysteine	0.37	0.57	0.16	0.66
Glutamine	3.97	3.77	1.37	8.04
Glycine	1.03	1.05	0.31	1.92
Proline	1.07	2.20	0.64	2.14
Serine	1.14	1.15	0.30	2.01
Tyrosine	—	0.93	0.24	1.71

Chemical Analysis

Samples of pea chips, DDGS, corn, SBM, and all diets were analyzed in duplicate (Table 1) for DM (method 930.15; AOAC, 2007), CP (method 990.03; AOAC, 2007), ADF (method 973.18; AOAC, 2007), and NDF (Holst, 1973). Amino acids were analyzed on a Hitachi Amino Acid Analyzer, Model No. L8800 (Hitachi High Technologies America Inc., Pleasanton, CA) using ninhydrin for postcolumn derivatization and norleucine as the internal standard. Before analysis, samples were hydrolyzed with 6 *N* HCl for 24 h at 110°C (method 982.30 E(a); AOAC, 2007). Methionine and cysteine were determined as methionine sulfone and cysteic acid after cold performic acid oxidation overnight before hydrolysis (method 982.30 E(b); AOAC, 2007). Tryptophan was determined after NaOH hydrolysis for 22 h at 110°C (method 982.30 E(c); AOAC, 2007). Diets and ingredients were also analyzed for calcium and phosphorus by inductively coupled plasma spectroscopy (method 985.01; AOAC, 2007) after wet ash sample preparation (method 975.03; AOAC, 2007), and diets were analyzed for ash (method 942.05; AOAC, 2007). Pea chips (Dakota Dry Bean Inc., Crary, ND) and Dakota Gold DDGS (Poet Nutrition, Sioux Falls, SD) were procured, and corn and SBM were sourced locally. The same batch of each feed ingredient was used in all diets throughout the experiment.

Pigs were fed growing diets until they were approximately 60 kg, early finisher diets until they were approximately 90 kg, and late finisher diets until the conclusion of the experiment when pigs had an average BW of 123.5 ± 2.37 kg. Three diets were formulated within each phase (Tables 2 and 3). The control diet in each phase was based on corn and SBM and contained 28.0, 21.4, and 16.2% SBM in the growing, early finishing, and late finishing diets, respectively.

The second treatment group received diets in which 50% of the SBM was replaced by DDGS and pea chips, and the inclusion of SBM in these diets was 14.0, 10.7, and 8.2% in grower, early finisher, and late finisher diets, respectively. The inclusion of DDGS and pea chips in these diets was 15.0 and 20.0%, 11.5 and 15.3%, and 8.6 and 11.6% in growing, early finishing, and late finishing diets, respectively. The last treatment group received diets in which all the SBM was replaced by DDGS and pea chips, and the inclusion of DDGS and pea chips in these diets was 30.0 and 40.0%, 23.0 and 30.6%, and 17.2 and 23.2% in growing, early finishing, and late finishing diets, respectively. The ratio of DDGS and pea chips was kept constant at 3:4 across all diets. This ratio was chosen because it allowed corn and SBM to be replaced without increasing dietary CP concentration. Diets were also balanced for all indispensable amino acids by inclusion of synthetic amino acids lysine, methionine, and tryptophan. All diets were formulated on the basis of analyzed values for nutrient composition of corn, SBM, pea chips, and DDGS. Within each phase, diets were formulated to contain constant concentrations of standardized ileal digestible indispensable amino acids and also constant concentrations of digestible phosphorus. Pigs were allowed ad libitum access to feed and water throughout the experiment.

Daily feed allotments were recorded, and feed left in the feeders was recorded at the end of each phase. Individual pig BW was recorded at the start of the experiment and at the end of each phase. Data were summarized at the conclusion of the experiment, and ADG, ADFI, and G:F were calculated for each pig and summarized within treatment group and phase. At the start and conclusion of the late finishing phase, pigs were also ultrasonically scanned for backfat thickness and loin eye area between the 10th and the 11th rib location by a trained operator who used an Aloka 500 SSD Ultrasound machine fitted with a 3.5-MHz, 12-cm linear array transducer (Corometrics Medical Systems Inc., Wallingford, CT).

Carcass Measurements and Taste Panels

Pigs were weighed off the experiment in the afternoon of the last day of the experiment, and feeders were removed from the pens to allow 18-h feed withdrawal before slaughter. All pigs were transported to the North Dakota State University Meats Laboratory on the morning of slaughter, where pigs were weighed and slaughtered in random order. After evisceration and inspection by USDA inspectors, the HCW was recorded. Carcasses were split down the midline, and split carcasses were stored at 4°C for 72 h. The pH of the longissimus dorsi (**LD**), serratus ventralis (**SV**), and gluteus medius (**GM**) muscles from the left side of

Table 2. Ingredient composition of experimental diets in which pea chips and distillers dried grains with solubles (DDGS) replaced soybean meal (SBM; as-fed basis)

	Grower diets, SBM replacement, %			Early finisher diets, SBM replacement, %			Late finisher diets, SBM replacement, %		
Ingredient, %	0	50	100	0	50	100	0	50	100
Corn	67.45	46.51	25.55	74.35	58.28	42.25	79.7	67.54	55.57
DDGS	—	15.00	30.00	—	11.50	23.00	—	8.60	17.20
SBM, 46% CP	28.00	14.00	—	21.40	10.70	—	16.20	8.20	—
Pea chips	—	20.00	40.00	—	15.30	30.60	—	11.60	23.20
Soybean oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	0.94	1.17	1.41	0.80	1.00	1.15	0.81	0.95	1.05
Monocalcium phosphate	0.81	0.41	—	0.63	0.33	—	0.44	0.20	—
Lysine-HCl	0.10	0.15	0.20	0.12	0.15	0.20	0.15	0.18	0.21
DL-Methionine	—	0.04	0.08	—	0.02	0.05	—	—	0.02
L-Tryptophan	—	0.02	0.06	—	0.02	0.05	—	0.03	0.05
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin premix[1]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Mineral premix[2]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

[1]The vitamin premix provided the following quantities of vitamins per kilogram of complete diet: vitamin A, 11,000 IU as vitamin A acetate; vitamin D_3, 1,650 IU; vitamin E, 55 IU as α tocopherol acetate; menadione, 4.4 mg as menadione dimethylpyrimidinol bisulphite; thiamin, 3.3 mg as thiamine mononitrate; riboflavin, 9.9 mg; pyridoxine, 3.3 mg as pyridoxine hydrochloride; vitamin B_{12}, 0.044 mg; D-pantothenic acid, 33 mg as calcium pantothenate; niacin, 55 mg; folic acid, 1.1 mg; biotin, 0.17 mg.

[2]The micromineral premix provided the following quantities of minerals per kilogram of complete diet: Cu, 16.5 mg as copper sulfate; Fe, 165 mg as ferrous sulfate; I, 0.30 mg as ethylenediamine dihydriodide; Mn, 43.5 mg as manganese sulfate; Se, 0.30 mg as sodium selenite; Zn, 165 mg as zinc sulfate.

Table 3. Analyzed nutrient composition of experimental diets in which soybean meal (SBM) was replaced by pea chips and distillers dried grains with solubles (DDGS; as-fed basis)

	Grower diets, SBM replacement, %			Early finisher diets, SBM replacement, %			Late finisher diets, SBM replacement, %		
Item	0	50	100	0	50	100	0	50	100
DM, %	88.76	89.22	90.01	88.36	89.02	89.57	89.38	89.47	89.56
Ash, %	5.74	5.81	6.06	5.32	4.89	5.05	4.61	4.10	3.67
ME,[1] kcal/kg	3,365	3,398	3,431	3,391	3,416	3,442	3,409	3,428	3,447
CP, %	20.3	20.41	19.80	16.46	16.45	16.95	14.42	14.38	14.30
NDF, %	14.92	17.81	22.84	11.56	18.52	20.29	14.19	16.87	18.70
ADF, %	3.13	4.14	6.10	3.44	4.13	5.33	2.91	3.45	3.82
Calcium, %	0.90	0.83	0.99	0.62	0.60	0.58	0.46	0.45	0.48
Phosphorus, %	0.88	0.90	0.78	0.79	0.69	0.69	0.66	0.65	0.58
Indispensable amino acids,%									
Arginine	1.15	1.24	1.39	1.00	1.00	1.04	0.82	0.85	0.88
Histidine	0.50	0.51	0.56	0.45	0.43	0.44	0.38	0.39	0.37
Isoleucine	0.76	0.76	0.80	0.67	0.62	0.60	0.55	0.54	0.50
Leucine	1.58	1.68	1.93	1.47	1.47	1.54	1.28	1.31	1.30
Lysine	1.07	1.16	1.24	1.03	0.95	1.00	0.86	0.84	0.84
Methionine	0.27	0.31	0.38	0.26	0.25	0.29	0.23	0.21	0.23
Phenylalanine	0.89	0.90	0.97	0.78	0.75	0.75	0.66	0.65	0.63
Threonine	0.64	0.65	0.72	0.57	0.55	0.56	0.48	0.46	0.46
Tryptophan	0.23	0.20	0.20	0.20	0.18	0.16	0.16	0.16	0.14
Valine	0.87	0.92	1.00	0.80	0.77	0.77	0.67	0.67	0.64
Dispensable amino acids, %									
Alanine	0.93	1.00	1.20	0.87	0.90	0.95	0.77	0.79	0.80
Asparagine	1.78	1.71	1.74	1.52	1.39	1.32	1.25	1.17	1.12
Cysteine	0.29	0.30	0.37	0.28	0.27	0.28	0.25	0.24	0.24
Glutamine	3.02	2.93	3.09	2.70	2.54	2.48	2.29	2.24	2.13
Glycine	0.74	0.75	0.85	0.66	0.65	0.65	0.56	0.55	0.55
Proline	1.05	1.10	1.24	1.00	0.99	1.09	0.87	0.89	0.87
Serine	0.70	0.70	0.80	0.63	0.62	0.64	0.54	0.51	0.53
Tyrosine	0.68	0.61	0.59	0.54	0.52	0.52	0.44	0.46	0.42

[1]Values for ME were calculated rather than analyzed (NRC, 1998).

each carcass was recorded at 45 min, 3 h, 24 h, and 72 h postslaughter. Live slaughter weight and HCW were used to calculate dressing percentage for each pig. Carcasses were split between the 10th and the 11th rib to measure LD area and 10th-rib backfat thickness. Carcass weight, LD area, and 10th-rib backfat measurements were used to calculate percent carcass lean (NPB, 2000). The left side of each carcass was cut into primals 72 h postmortem. Loin muscle, SV from the Boston butt, and GM in the ham face were allowed a minimum 10-min bloom time, and objective Minolta color measurements L*(black = 0 to white = 100), a* (positive value = red, negative value = green), and b* (positive value = blue, negative values = yellow) were taken using a Minolta Chroma Meter CR 410 (Minolta Corp., Ramsey, NJ) with D_{65} illuminant calibrated to a white plate. The second layer of BF at the 10th-rib loin muscle was exposed for Minolta evaluation. Subjective color score, marbling score (NPPC, 1999), and Japanese color score standards (Nakai et al., 1975) were determined by a single evaluator. One loin chop (2.54 cm) was removed immediately cranial to the 10th rib from each loin, weighed, and suspended from a fish hook (barb removed) for 24 h at 4°C. Chops were then reweighed to determine drip loss as the percentage disappearance of initial weight. Chops were covered with wax paper while suspended to avoid surface dehydration.

The 10th through the last rib section of the LD was vacuum packaged 72 h postmortem and aged for 10 d at 4°C for determination of loin purge loss. Two 2.54-cm-thick chops were then removed caudal to the 11th and the 12th rib. One chop was stored at −20°C until use in the palatability evaluations. The other chop was weighed and cooked on a clamshell-style grill (George Foreman, model GRP 99, Lake Forest, IL) to an internal temperature of 70°C and weighed again to determine cook loss.

A thermometer (thermocouple Model HH 801B, Omega Engineering Inc., Stamford, CT) was inserted in the chop to monitor internal temperature during cooking. Chops were cooled until they had reached a temperature of approximately 20°C. Six circular cores (1-cm diameter) were removed from each chop parallel to the length of the muscle fibers, and shear force was determined by Warner-Bratzler shear force (G-R Electric Manufacturing Company, Manhattan, KS). The mean shear force value for each LD chop was used for statistical analysis.

Pork Chop Palatability

A 6-member trained panel (AMSA, 1995) was used to evaluate loin chops for tenderness, juiciness, pork flavor intensity, and off-flavor using 8-point hedonic scales (8 = extremely tender, extremely juicy, extremely flavorful, and no off-flavor; 1 = extremely tough, extremely dry, extremely bland, and extreme off-flavor). Frozen chops were thawed for approximately 24 h at 3°C. Each chop (2.54 cm thick) was cooked on a George Foreman clamshell-style grill to an internal temperature of 70°C, which was monitored using a thermocouple thermometer. Edges were removed and chops were cut into 1.27-cm^2 cubes and served warm. Panelists were assigned to a partitioned booth that had a red filtered light and was separate from the preparation area. Panelists were given unsalted crackers, distilled water, and part-skim ricotta cheese for palate cleansing along with an empty cup for sample expectoration. Samples were presented to panelists in a random order, and samples from the same loin were given to each panelist at the same time. Each panelist received one cube in a plastic soufflé cup. Panelists evaluated 8 samples per day for 3 d.

Bellies from each pig were separated from the left carcass side 72 h postslaughter, and subjective belly flop scores were recorded. Bellies were suspended at the longitudinal midpoint of the belly across a steel rod. Bellies were then scored subjectively using a line scale from 0 to 10, with 0 representing a very soft belly and 10 a very firm belly (adapted from Thiel-Cooper et al., 2001).

Statistical Analysis

Data were analyzed using the PROC GLM of SAS (Littell et al.,

Table 4. Effects of replacing soybean meal (SBM) with pea chips and distillers dried grains with solubles (DDGS) on growth performance of growing-finishing pigs[1]

	SBM replacement, %			Sex		SEM		*P*-value[2]		
								Treatment		
Item	0	50	100	Barrow	Gilt	Treatment	Sex	Linear	Quadratic	Sex
Grower period[3]										
Initial wt, kg	23.29	23.01	23.24	23.33	23.03	0.378	0.309	0.92	0.59	0.50
ADG, kg	0.98	0.95	0.88	0.97	0.90	0.021	0.017	<0.01	0.41	0.01
ADFI, kg	2.19	2.14	1.96	2.17	2.02	0.048	0.039	<0.01	0.26	0.01
G:F, kg/kg	0.45	0.44	0.45	0.45	0.45	0.009	0.007	0.85	0.65	0.87
Final wt, kg	64.55	63.01	60.17	64.24	60.91	1.037	0.847	0.01	0.61	0.01
Early finishing period[3]										
ADG, kg	1.07	1.00	1.00	1.05	0.99	0.031	0.025	0.16	0.32	0.09
ADFI, kg	2.78	2.63	2.60	2.86	2.48	0.088	0.072	0.18	0.56	<0.01
Avg. G:F, kg/kg	0.39	0.38	0.39	0.37	0.40	0.009	0.007	0.92	0.62	0.01
Final wt, kg	93.35	89.89	87.22	92.69	87.61	1.381	1.127	0.01	0.82	0.01
Late finishing period[3]										
ADG, kg	0.98	0.99	0.98	0.98	0.98	0.043	0.035	1.00	0.87	0.95
ADFI, kg	2.94	3.09	2.86	2.94	2.99	0.054	0.044	0.33	0.01	0.51
Avg. G:F, kg/kg	0.33	0.32	0.34	0.34	0.33	0.015	0.012	0.64	0.35	0.66
10th-rib backfat, % change	23.42	33.20	40.26	29.04	35.54	5.251	4.288	0.04	0.84	0.30
Loin eye area, % change	36.65	37.61	36.77	36.61	37.41	0.975	0.796	0.93	0.46	0.48
Final wt, kg	126.59	123.52	120.45	126.03	121.02	2.374	1.939	0.09	1.00	0.09
Overall										
ADG, kg	1.00	0.98	0.94	1.00	0.95	0.022	0.018	0.08	0.91	0.09
ADFI, kg	2.59	2.58	2.43	2.61	2.46	0.045	0.037	0.02	0.19	0.01
Avg. G:F, kg/kg	0.39	0.38	0.39	0.38	0.39	0.008	0.006	0.82	0.30	0.58

[1]Data are means of 8 observations per treatment.

[2]The interaction between treatment and sex was not significant ($P > 0.05$) and, therefore, was removed from the final model.

[3]Grower period = 42 d on feed, early finishing period = 27 d on feed, and late finishing period = 34 d on feed.

1996; SAS Institute Inc., Cary, NC). Pig was the experimental unit for all analyses. The model included treatment, sex, weight block, and their respective interactions (treatment × sex, treatment × weight block, and sex × weight block) as main effects. However, no interactions were observed; thus all interactions were removed from the final model and only main effects of treatment and sex are reported. Linear and quadratic orthogonal contrasts were used to measure the effects of treatment. An α value of 0.05 was used to assess significance among treatments, and P-values greater than 0.05 and smaller than 0.10 were considered tendencies.

RESULTS AND DISCUSSION

There were no significant interactions between dietary treatments and sex for any of the response variables. Therefore, effects of dietary treatments and sex are presented separately. Overall, gilts had lower ADFI ($P = 0.01$), live weight ($P = 0.01$), HCW ($P = 0.01$), 10th-rib backfat ($P = 0.01$), and belly firmness ($P = 0.02$) and tended to have lower ADG ($P = 0.09$) compared with barrows. Barrows tended to have lower percent lean meat ($P = 0.07$) and 10-d percent purge loss ($P = 0.08$) compared with gilts. These results are in agreement with previously reported data (Siers, 1975; Cromwell et al., 1993; Friesen et al., 1994; Cisneros et al., 1996; Warnants et al. 1996, 1999; Averette Gatlin et al., 2002, 2003; Wiseman et al., 2007a,b).

Pig Performance

During the grower period, ADG, ADFI, and final weight were reduced (linear, $P \leq 0.01$) as SBM was replaced by pea chips and DDGS, but there were no differences ($P > 0.65$) among treatments in G:F (Table 4). However, during the early finishing period no differences ($P > 0.16$) in ADG, ADFI, or G:F were observed, but the final weight at the end of the early finishing period was reduced (linear, $P = 0.01$) as SBM replacement increased. Pigs fed the diet in which 50% of the SBM was replaced by pea chips and DDGS during the late finishing period had greater ADFI compared with pigs fed diets with 0 or 100% replacement of SBM (quadratic, $P = 0.01$). Final weight at the end of the experiment tended to be reduced (linear, $P = 0.09$) as SBM replacement increased. There were no differences among treatments in ADG and G:F during the late finishing period ($P > 0.35$). However, the percent change in 10th-rib backfat during the late finishing period increased (linear, $P = 0.04$) with increasing SBM replacement, whereas there were no differences ($P > 0.46$) among

Table 5. Effects of replacing soybean meal (SBM) with pea chips and distillers dried grains with solubles (DDGS) on carcass quality[1]

	SBM replacement, %			Sex		SEM		*P*-value[2]		
Item	0	50	100	Barrow	Gilt	Treatment	Sex	Linear	Quadratic	Sex
Live wt, kg	125.63	121.71	119.32	125.49	118.94	1.987	1.623	0.04	0.76	0.01
HCW, kg	96.88	93.70	91.08	96.59	91.18	1.551	1.266	0.02	0.89	0.01
Dressing percentage	77.08	77.02	76.35	76.99	76.65	0.424	0.346	0.24	0.56	0.49
LD area, cm^2	51.49	48.35	50.33	50.81	49.30	2.409	1.967	0.74	0.40	0.59
10th-rib backfat, mm	2.45	2.95	2.56	2.97	2.33	0.188	0.153	0.68	0.07	0.01
Lean meat, kg	50.27	46.14	46.89	47.92	47.61	1.319	1.077	0.09	0.15	0.84
Lean meat,[3] %	51.96	49.26	51.53	49.63	52.20	1.166	0.952	0.80	0.10	0.07
Marbling	1.75	1.50	1.50	1.67	1.50	0.260	0.212	0.51	0.70	0.59
Longissimus dorsi pH										
45 min	6.22	6.02	6.09	6.14	6.08	0.063	0.051	0.15	0.09	0.44
24 h	5.35	5.39	5.34	5.38	5.34	0.050	0.041	0.81	0.45	0.43
Gluteus medius pH										
45 min	6.10	6.08	6.26	6.09	6.20	0.097	0.079	0.25	0.41	0.33
24 h	5.72	5.88	5.51	5.76	5.65	0.106	0.086	0.18	0.05	0.40
Serratus ventralis pH										
45 min	6.22	6.33	6.15	6.23	6.23	0.051	0.041	0.33	0.04	0.99
24 h	5.71	5.75	5.66	5.76	5.66	0.113	0.093	0.73	0.64	0.47
Belly firmness[4]	6.11	5.49	3.63	6.26	3.89	0.807	0.659	0.04	0.54	0.02
24-h drip loss, %	3.41	3.75	4.32	3.43	4.22	0.489	0.399	0.21	0.85	0.18
10-d purge loss, %	4.43	4.48	4.45	3.83	5.08	0.587	0.479	0.98	0.96	0.08

[1]Data are means of 8 observations per treatment.

[2]The interaction between treatment and sex was not significant ($P > 0.05$) and, therefore, was removed from the final model.

[3]Calculated according to National Pork Producers Council (NPPC, 1999).

[4]Belly firmness values are subjective measures where 0 = extremely soft belly and 10 = extremely firm.

treatments in the percent change of loin eye area from the beginning to the end of the late finishing period. Throughout the entire feeding period, ADFI was reduced (linear, $P = 0.02$) and ADG tended to be reduced (linear, $P = 0.08$) as SBM was replaced by pea chips and DDGS, but there were no differences ($P > 0.30$) among treatments in G:F. The reduction in overall feed intake and daily gain we observed was mainly caused by a reduction in ADFI and ADG during the grower period. This observation is similar to data reported by Widmer et al. (2008), who observed that pigs fed diets in which high-protein DDGS replaced SBM had reduced ADFI and ADG in the growing period but not in the early and late finishing phases. In contrast, when field peas replaced all of the SBM in diets of growing and finishing pigs, no differences in ADFI and ADG were observed in any phase (Stein et al., 2006). Likewise, no differences in ADFI and ADG were observed when pea chips replaced SBM in diets fed to pigs during the early and late finishing periods (Newman et al., 2011). The reason for the reduced ADFI and ADG in the growing period observed in this experiment may be attributed to reduced palatability of a diet containing 40% pea chips and 30% DDGS. It has been shown that pigs prefer to eat corn-SBM diets rather than corn-SBM-DDGS diets (Hastad et al., 2005; Seabolt et al., 2008). Diets containing 30% DDGS cause reduced ADFI in some experiments (Whitney et al., 2006; Hinson et al., 2007), although that is not always the case (Cook et al., 2005; DeDecker et al., 2005).

Table 6. Effects of replacing soybean meal (SBM) with pea chips and distillers dried grains with solubles (DDGS) on carcass and fat coloration[1]

	SBM replacement, %			Sex		SEM		*P*-value[2]		
Item	0	50	100	Gilt	Barrow	Treatment	Sex	Linear	Quadratic	Sex
Longissimus dorsi										
Color[3]	2.38	2.13	2.00	2.17	2.17	0.180	0.147	0.16	0.78	1.00
Color, L*[4]	61.38	62.92	63.58	62.56	62.69	1.073	0.876	0.17	0.74	0.92
Color, a*[4]	19.06	19.68	19.58	19.23	19.66	0.369	0.301	0.34	0.44	0.33
Color, b*[4]	7.07	7.42	7.90	7.23	7.70	0.421	0.344	0.19	0.90	0.35
Color saturation[5]	20.36	21.05	21.13	20.56	21.13	0.429	0.350	0.22	0.56	0.27
Hue angle[6]	20.35	20.55	21.94	20.56	21.34	0.986	0.805	0.27	0.63	0.50
JCSS[7]	2.50	2.00	2.00	2.17	2.17	0.227	0.185	0.14	0.38	1.00
Gluteus medius										
L*	58.21	56.97	61.06	57.74	59.76	1.880	1.535	0.30	0.26	0.36
a*	21.53	21.50	22.03	21.63	21.75	0.274	0.223	0.21	0.42	0.71
b*	7.85	6.51	8.65	7.48	7.86	0.619	0.506	0.37	0.03	0.60
Color saturation	22.97	22.52	23.69	22.96	23.17	0.372	0.304	0.19	0.09	0.64
Hue angle	89.65	89.56	89.70	89.62	89.65	0.036	0.029	0.35	0.02	0.41
Serratus ventralis										
L*	49.82	49.80	52.90	51.63	50.05	1.670	1.364	0.21	0.45	0.43
a*	24.63	23.77	25.88	24.71	24.81	0.509	0.416	0.10	0.03	0.86
b*	8.06	6.86	9.70	8.34	8.08	0.729	0.596	0.13	0.04	0.76
Color saturation	25.98	24.77	27.66	26.11	26.16	0.684	0.558	0.10	0.03	0.95
Hue angle	17.83	15.95	20.41	18.45	17.68	1.281	1.046	0.17	0.06	0.61
10th-rib fat[8]										
L*	81.18	79.65	80.55	81.30	79.62	0.863	0.705	0.61	0.27	0.11
a*	9.60	10.11	9.35	9.55	9.83	0.376	0.307	0.64	0.18	0.54
b*	1.39	1.03	2.09	1.45	1.56	0.269	0.220	0.09	0.05	0.75

[1]Data are means of 8 observations per treatment.

[2]The interaction between treatment and sex was not significant ($P > 0.05$) and, therefore, was removed from the final model.

[3]Calculated according to National Pork Producers Council (NPPC, 1999).

[4]Color measurements: L* = lightness, white = 100, black = 0; a* = redness, positive a* = red, negative a* = green; b* = yellowness, positive b* = yellow, negative b* = blue.

[5]Color saturation = $(a^*)^2 + (b^*)^2$, whereby a greater number is more vivid.

[6]Hue angle = arctangent (b*/a*) × (360°/2 × 3.14), expressed in degrees where 0° is true red and 90° is true yellow.

[7]JCSS = Japanese color score standard: 1 = pale gray through 6 = dark purple (Nakai et al., 1975).

[8]Fat color scores were obtained at the 10th-rib location in the second layer of fat, counting from the skin inward.

Table 7. Effects of replacing soybean meal (SBM) with pea chips and distillers dried grains with solubles on the palatability of pork chops[1]

	SBM replacement, %			Sex		SEM		*P*-value[2]		
Item	0	50	100	Gilt	Barrow	Treatment	Sex	Linear	Quadratic	Sex
Cook loss, %	18.28	18.81	19.11	17.84	19.63	1.023	0.836	0.58	0.93	0.15
Shear force, kg	2.70	2.50	2.48	2.68	2.44	0.139	0.113	0.27	0.58	0.14
Pork chop palatability										
Tenderness[3]	5.45	5.60	5.16	5.31	5.50	0.195	0.167	0.31	0.24	0.46
Juiciness[4]	5.70	5.78	5.38	5.62	5.63	0.202	0.172	0.28	0.33	0.97
Flavor[5]	5.75	5.74	5.35	5.62	5.61	0.137	0.117	0.05	0.29	0.95

[1]Data are means of 8 observations per treatment.

[2]The interaction between treatment and sex was not significant ($P > 0.05$) and, therefore, was removed from the final model.

[3]Tenderness score: 8 = extremely tender; 1 = extremely tough.

[4]Juiciness score: 8 = extremely juicy; 1 = extremely dry.

[5]Flavor intensity: 8 = extremely flavorful; 1 = extremely bland.

Carcass Composition and Quality

There was a linear reduction in live weight ($P = 0.04$), HCW ($P = 0.02$), and belly firmness ($P = 0.04$) and a tendency for less lean meat (linear, $P = 0.09$) as pea chips and DDGS replaced SBM (Table 5). Pigs fed pea chips and DDGS had a greater percent increase (linear, $P = 0.04$) in 10th-rib backfat as measured by live ultrasound in the late finishing period (Table 4). This is in agreement with the final carcass backfat thickness data where pigs receiving diets without pea chips and DDGS tended to have lower (quadratic, $P = 0.07$) 10th-rib backfat among treatments (Table 5). Pigs fed the diet in which 50% of the SBM was replaced by pea chips and DDGS had a higher 45-min pH of the SV compared with pigs fed diets with 0 or 100% replacement of SBM (quadratic, $P = 0.04$). There was no difference ($P > 0.25$) in 45-min pH of the GM with increasing SBM replacement. However, there was a tendency for an increase (quadratic, $P = 0.09$) of the 45-min pH of the LD muscle in the ham when pea chips and DDGS were not present in the diet (Table 5). In addition, pigs fed the diet in which 50% of the SBM was replaced by pea chips and DDGS had greater (quadratic, $P = 0.05$) 24-h pH of the GM compared with pigs fed diets with 0 or 100% replacement of SBM (Table 5). However, there was no difference ($P > 0.45$) in 24-h pH of the SV and LD with increasing SBM replacement. Moreover, dressing percent, LD area, percent lean meat, marbling, 24-h percent drip loss, and 10-d percent purge loss were not influenced ($P > 0.10$) by replacement of SBM with pea chips and DDGS (Table 5).

Replacement of SBM with pea chips and DDGS did not affect ($P > 0.14$) overall color, L*, a*, b*, color saturation, hue angle, and Japanese color score standards of the LD (Table 6). Pigs fed the diet in which 50% of the SBM was replaced with pea chips and DDGS had the lowest b* (quadratic, $P = 0.03$) and hue angle (quadratic, $P = 0.02$) and tended to have the lowest color saturation (quadratic, $P = 0.09$) in the GM muscle. Similarly, there were treatment differences for a* (quadratic, $P = 0.03$), b* (quadratic, $P = 0.04$), and color saturation (quadratic, $P = 0.03$) in the SV, where pigs fed a diet containing 50% SBM replacement with pea chips and DDGS had lower a*, b*, and color saturation values compared with pigs fed a diet in which 0 or 100% of the SBM was replaced with pea chips and DDGS. In addition, hue angle value of the SV muscle tended (quadratic, $P = 0.06$) to be lower for pigs fed 50% SBM replacement compared with pigs fed diets in which 0 or 100% of the SBM was replaced by pea chips and DDGS. Moreover, pigs that were fed 50% SBM replacement had lower (quadratic, $P = 0.05$) b* of 10th-rib fat color compared with pigs fed 0 or 100% SBM replacement.

The lack of diet effects on dressing percentage, LD area, lean meat percent, marbling, 24-h percent drip loss, and 10-d percent purge loss demonstrates that carcass composition is not influenced by the inclusion of pea chips and DDGS in the diets. The reduction in belly firmness is consistent with previous data on pigs fed diets containing DDGS (Whitney et al., 2006; Widmer et al., 2008; Stein and Shurson, 2009).

Palatability

There were no differences ($P > 0.27$) among treatments for percent cook loss and shear force (Table 7). In addition, tenderness and juiciness of pork chops did not differ ($P > 0.24$) among treatments. In this experiment, tenderness of pork was not different among treatments, which is not consistent with Newman et al. (2011), who reported a linear decrease in tenderness scores as inclusion of pea chips in the diet increased to 45 and

30% in early and late finishing diets, respectively. It is possible that the DDGS that was used in this experiment may have mitigated the negative effects of tenderness as reported by Newman et al. (2011). To our knowledge there are no published data on palatability of pork chops from pigs fed diets containing DDGS at the levels used in the grower period of this experiment. There are also no data reporting palatability of pork chops from pigs fed a combination of pea chips and DDGS.

However, values for flavor were decreased (linear, $P = 0.05$) as SBM was replaced by pea chips and DDGS. There was a reduction of flavor in pork chops from pigs fed diets with no SBM, but it is unclear what caused this change. Pea chips have been reported to have no influence on pork chop flavor (Newman et al., 2011), but we are unaware of any data on the effect of DDGS on pork flavor.

IMPLICATIONS

Data from this experiment indicate that live weight and HCW are reduced if pigs are fed diets in which SBM is replaced by pea chips and DDGS. Therefore, these diets could be economical to use only if the cost is less expensive than the typical corn-SBM diets. Among the measures of carcass quality, the reduction in belly firmness that was observed as pea chips and DDGS replaced SBM in the diets may present processing challenges to the industry and negatively affect the value of the carcass.

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