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Effects of pea chips on pig performance, carcass quality and composition, and palatability of pork[1]

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ABSTRACT: Pea chips are produced as a by-product when field peas are processed to produce split peas for human consumption. The objective of this experiment was to test the hypothesis that inclusion of pea chips in diets fed to finishing pigs does not negatively influence pig growth performance, carcass composition, and the palatability of pork. A total of 24 barrows (initial BW: 58.0 ± 6.6 kg) were allotted to 1 of 4 treatments and fed early finishing diets for 35 d and late finishing diets for 35 d. A corn-soybean meal (SBM) control diet and 3 diets containing pea chips were formulated for each phase. Pea chips replaced 33.3, 66.6, or 100% of the SBM in the control diet. Pigs were housed individually, and all pigs were slaughtered at the conclusion of the experiment. Overall, there were no differences ($P >$ 0.11) in final BW, ADFI, and G:F of pigs among treatments, but there was a quadratic response in ADG (P = 0.04), with the smallest value observed in pigs fed the control diet. Dressing percentage linearly decreased (P = 0.04) as pea chips replaced SBM in diets, but there were no differences ($P >$ 0.20) among treatments in HCW, LM area, 10th-rib backfat, lean meat percentage, and marbling. Likewise, pH in loin and ham, drip loss, and purge loss were not influenced ($P >$ 0.13) by treatment. However, there was a quadratic response (P = 0.08) in 24-h pH in the shoulder, with the smallest value present in pigs fed the diet, in which 66.6% of the SBM was replaced by pea chips. Subjective LM color and Japanese color score standard were reduced (quadratic, P = 0.03 and 0.05, respectively) and LM b* values and hue angle were increased (quadratic, P = 0.09 and 0.10, respectively) when pea chips replaced SBM in the diets. Ham L* (quadratic, P = 0.04), a* (linear, P = 0.02), b* (quadratic, P = 0.07), color saturation (linear, P = 0.02), and hue angle (quadratic, P = 0.05) were increased when pea chips replaced SBM. However, there were no differences ($P >$ 0.16) in shoulder and fat color. Moreover, cook loss percentage, shear force, juiciness, and pork flavor of pork chops were not different ($P >$ 0.10) among treatments, but tenderness of pork chops linearly decreased (P = 0.04) as SBM replaced pea chips. It is concluded that all the SBM in diets fed to growing-finishing pigs may be replaced by pea chips without negatively influencing growth performance or carcass composition. However, pigs fed pea chips will have pork chops and hams that are lighter, and chops may be less tender if pigs are fed pea chips rather than corn and SBM.

Key words: carcass composition, palatability, pea chip, pig, pork, quality

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INTRODUCTION

Pea chips are a by-product of the pea-processing industry. When peas are processed for production of split peas for human consumption, a certain percentage of the peas are crushed during the splitting process. These peas are commonly known as pea chips, and they are usually sold at a competitive price to the livestock feed industry.

The total production of field peas in the United States in 2009 was approximately 800,000 t, which is the greatest production since 1928 (NASS, 2010). The 2009 production of field peas was approximately 42% greater than production in 2008, and approximately 66% of the total US production of field peas is harvested in North Dakota (NASS, 2010). Because of the increase in the production of field peas, it is expected that the production of pea chips will also increase.

Pea chips contain slightly more CP, ADF, and NDF than regular field peas (Igbasan and Guenter, 1996). Pea chips may be included in diets fed to broiler chickens by up to 15%, but at greater inclusion rates, chick performance can be reduced (Igbasan and Guenter, 1996). Field peas can replace all the soybean meal in

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diets fed to growing-finishing pigs without negatively influencing pig growth performance, carcass composition, and the palatability of pork (Stein et al., 2006). To our knowledge, however, there are no data on the effect of including pea chips in diets fed to finishing pigs on growth performance, and it is not known how dietary pea chips affect the carcass composition of pigs or the palatability of pork. It was, therefore, the objective of this experiment to test the hypothesis that inclusion of pea chips in corn- and soybean meal-based diets fed to finishing pigs does not influence pig growth performance, carcass composition, or pork palatability.

MATERIALS AND METHODS

The protocol for this experiment was reviewed and approved by the Institutional Animal Care and Use Committee at North Dakota State University.

Animals and Housing

Twenty-four finishing barrows (initial BW: 58.0 ± 6.6 kg) were obtained from the North Dakota State University Swine Research Unit. Pigs were the offspring of 1/2 Hampshire × 1/2 Duroc boars mated to 1/4 Duroc × 1/4 Landrace × 1/2 Yorkshire females. Before the start of the experiment, pigs were transported approximately 1.6 km to the North Dakota State University Animal Nutrition and Physiology Center, where they were randomly allotted to 1 of 4 treatment groups with 6 pigs per treatment. Pigs were individually housed in 0.89 × 1.47 m pens with slatted floors. The pens were in an environmentally controlled building with temperature maintained between 18 and 22°C. Each pen had a 1-hole feeder and a nipple drinker. The experiment was conducted from August to October, 2008.

Diets, Feeding, and Live Data Recording

Pea chips were obtained from a commercial company (Dakota Dry Bean Inc., Crary, ND), and corn and soybean meal were sourced locally. Nutrient composition is present in Table 1. Early finisher diets were fed during the initial 35 d of the experiment and late finisher diets were fed during the final 35 d. Four diets were formulated for each phase (Tables 2 and 3). The control diet for the early finisher pigs was a corn- and soybean meal-based diet that contained 18% soybean meal and 0.15% L-Lys·HCl. Three additional diets were formulated by including 15, 30, or 45% pea chips to the control diet at the expense of corn and soybean meal. The inclusion of soybean meal in these diets was 12, 6, or 0%, respectively. The inclusion of L-Lys·HCl was reduced as the inclusion of pea chips increased, but DL-Met, L-Thr, and L-Trp were included in the diets that contained pea chips. The control diet for late finishing pigs contained 12% soybean meal. The 3 pea chip-containing diets fed during the late finishing phase contained 10, 20, or 30% pea chips, respectively, and soybean meal was included at 8, 4, or 0% in these diets. Thus, in both phases, pea chips replaced 33.3, 66.6, or 100% of the soybean meal in the diets. The inclusion of minerals and vitamins was calculated to meet or exceed current requirement estimates for finishing pigs (NRC, 1998).

Table 1. Analyzed nutrient composition of pea chips, corn, and soybean meal (%; as-fed basis)

Item	Ingredient: Pea chips	Corn	Soybean meal
DM	91.20	89.21	90.61
CP	23.40	8.51	49.57
ADF	6.77	1.53	3.62
NDF	7.23	7.31	7.33
Ca	0.10	0.01	0.44
P	0.43	0.32	0.66
Indispensable AA			
Arg	2.08	0.36	3.30
His	0.57	0.22	1.21
Ile	0.92	0.28	2.05
Leu	1.63	0.91	3.55
Lys	1.67	0.25	2.93
Met	0.25	0.17	0.65
Phe	1.08	0.37	3.31
Thr	0.88	0.26	1.77
Trp	0.20	0.07	0.71
Val	1.04	0.38	2.15
Dispensable AA			
Ala	1.02	0.56	1.97
Asp	2.67	0.50	5.21
Cys	0.37	0.16	0.66
Glu	3.97	1.37	8.04
Gly	1.03	0.31	1.92
Pro	1.07	0.64	2.14
Ser	1.14	0.30	2.01
Tyr	—	0.24	1.71

Pigs were allowed feed and water on an ad libitum basis throughout the experiment. Feed allotments were recorded daily and the weight of feed left in the feeders was recorded at the end of the early finishing phase and at the end of the experiment. The BW of each pig was recorded at the start of the experiment, at the end of the early finishing phase, and at the end of the experiment. Data for feed disappearance for each pen were summarized at the conclusion of the experiment, and the ADFI within each phase and treatment group was calculated. Data for pig BW gains were summarized as well, and ADG and G:F were calculated for each pen and summarized within each phase and treatment group.

Carcass Evaluations

Feed was withheld from pigs 18 h before slaughter. All pigs were transported to the NDSU Meat Laboratory on the morning of slaughter, and they were electrically stunned and exsanguinated. After evisceration and in-

Table 2. Ingredient composition of experimental diets in which pea chips replaced soybean meal (as-fed basis)

	Early finisher diet				Late finisher diet			
	Soybean meal replacement, %				Soybean meal replacement, %			
Ingredient, %	0.0	33.3	66.6	100.0	0.0	33.3	66.6	100.0
Ground corn	77.60	68.50	59.55	50.50	83.80	77.85	71.90	65.95
Soybean meal, 46% CP	18.00	12.00	6.00	—	12.00	8.00	4.00	—
Pea chips	—	15.00	30.00	45.00	—	10.00	20.00	30.00
Soybean oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Ground limestone	0.85	0.93	0.95	1.03	0.80	0.85	0.90	0.95
Monocalcium phopsphate	0.80	0.78	0.68	0.60	0.66	0.58	0.50	0.42
L-Lys·HCl	0.15	0.13	0.10	0.07	0.14	0.11	0.08	0.05
DL-Met	—	0.02	0.05	0.09	—	—	—	—
L-Thr	—	0.02	0.04	0.06	—	—	—	—
L-Trp	—	0.02	0.03	0.05	—	0.01	0.02	0.03
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin premix[1]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Micromineral premix[2]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[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 bisulfite; thiamine, 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; and 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; and Zn, 165 mg as zinc sulfate.

Table 3. Analyzed nutrient composition of experimental diets in which pea chips replaced soybean meal (%; as-fed basis)

	Grower diet				Finisher diet			
	Soybean meal replacement, %				Soybean meal replacement, %			
Item	0.0	33.3	66.6	100.0	0.0	33.3	66.6	100.0
DM	90.44	90.06	90.26	90.38	90.58	90.68	90.63	90.76
CP	15.85	15.41	15.99	15.72	13.21	13.54	13.93	13.69
ADF	2.10	2.10	1.96	2.47	1.92	1.65	1.90	1.94
NDF	7.47	6.57	7.00	6.80	6.74	6.27	6.39	5.97
Ash	4.64	4.38	4.06	4.08	4.16	4.11	4.03	3.75
Ca	0.73	0.62	0.58	0.60	0.59	0.62	0.62	0.57
P	0.52	0.50	0.47	0.44	0.47	0.47	0.45	0.41
Indispensable AA								
Arg	0.86	0.87	1.08	1.09	0.66	0.80	0.85	0.91
His	0.38	0.37	0.38	0.36	0.32	0.33	0.33	0.32
Ile	0.60	0.58	0.56	0.56	0.49	0.49	0.50	0.49
Leu	1.37	1.29	1.29	1.20	1.12	1.19	1.15	1.10
Lys	0.82	0.84	0.90	0.87	0.64	0.69	0.72	0.72
Met	0.23	0.23	0.25	0.27	0.19	0.20	0.18	0.17
Phe	0.70	0.69	0.73	0.70	0.57	0.62	0.62	0.60
Thr	0.51	0.50	0.56	0.55	0.39	0.44	0.42	0.41
Trp	0.17	0.17	0.17	0.17	0.15	0.15	0.16	0.15
Val	0.70	0.68	0.65	0.66	0.58	0.59	0.60	0.59
Dispensable AA								
Ala	0.80	0.76	0.77	0.72	0.57	0.70	0.68	0.66
Asp	1.30	1.26	1.41	1.33	1.00	1.09	1.11	1.11
Cys	0.23	0.23	0.24	0.20	0.20	0.21	0.21	0.20
Glu	2.54	2.41	2.51	2.33	2.08	2.18	2.14	2.07
Gly	0.58	0.57	0.60	0.58	0.47	0.51	0.51	0.51
Pro	0.89	0.83	0.80	0.72	0.76	0.77	0.74	0.68
Ser	0.58	0.56	0.64	0.57	0.44	0.52	0.50	0.48
Tyr	0.49	0.44	0.50	0.45	0.38	0.44	0.41	0.41

spection 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 LM, serratus ventrilis, and gluteus medius from the left side of each carcass was recorded at 45 min, 3, 24, 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 11th rib to measure LM area and 10th-rib backfat thickness. Carcass weight, LM area, and 10th-rib backfat measurements were used to calculate percentage carcass lean (NPB, 2000). The left side of each carcass was separated into primal cuts 72 h postmortem. Loin muscle, serratus ventrilis from the Boston butt, and gluteus medius in the ham face were allowed a minimum 10 min bloom time and objective color measurements, L* (black = 0 to white = 100), a* (positive value = red, and negative value = green), and b* (positive value = blue, and negative values = yellow) were taken on a freshly cut surface using a color meter (Chroma Meter CR 410, Minolta Corp., Ramsey, NJ) with D_{65} illuminant calibrated to a white plate. The second layer of backfat at the 10th-rib LM was exposed for the color evaluation. Subjective color score, marbling score (NPPC, 1999), and Japanese Color Score Standards (**JCSS**; Nakai et al., 1975) were determined by a single evaluator. One loin chop (2.54 cm) at the 11th rib was removed 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 while suspended to avoid surface dehydration.

The third through the 10th-rib section of the LM was vacuum packaged 72 h postmortem and aged for 10 d at 4°C for determination of loin purge loss (Stein et al., 2006). Two 2.54-cm-thick chops were then removed from the caudal end of each rib section. One chop was stored at −20°C until used in the palatability evaluations. The other chop was weighed and cooked on a clamshell style grill (model GRP 99, George Foreman, 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 while 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 LM 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 grill (George Foreman) 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 separate from the preparation area that had a red filtered light. 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 1 cube in plastic soufflé cups. Panelists evaluated 8 samples per day for 3 d.

Chemical Analysis

Samples of pea chips, corn, soybean meal, and all diets were analyzed in duplicate 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 with an AA 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 Cys were determined as Met 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 Ca and P 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).

Statistical Analysis

Data were analyzed using the Proc GLM (SAS Inst. Inc., Cary, NC). Mean separation was accomplished using the probability of difference procedure. All reported means are least squares means. Significance was set at $P < 0.05$, and P-values between 0.05 and 0.10 were considered to be trends. The pig was the experimental unit for all analyses, and the initial model included treatment and block with their interaction as fixed effects. However, treatment × block interactions were not significant ($P \geq 0.30$) and, therefore, were removed from the final model. Linear and quadratic orthogonal contrasts were used to determine effects of inclusion of pea chips in the diets.

Table 4. Effects of replacing soybean meal by pea chips on growth performance of growing-finishing pigs fed experimental diets[1]

	Soybean meal replacement, %					*P*-value	
Item	0.0	33.3	66.6	100.0	SEM	Linear	Quadratic
Early finisher period[2]							
Initial BW, kg	57.77	56.87	56.56	56.71	0.67	0.27	0.45
ADFI, kg	3.277	2.988	3.234	3.162	0.145	0.89	0.51
ADG, kg	1.054	1.106	1.089	0.981	0.045	0.24	0.08
G:F	0.323	0.371	0.342	0.314	0.018	0.50	0.05
Final BW, kg	94.61	95.51	94.61	90.97	1.55	0.11	0.16
Late finishing period[2]							
ADFI, kg	2.902	3.281	3.127	3.110	0.182	0.58	0.30
ADG, kg	0.929	1.050	1.004	1.024	0.065	0.39	0.41
G:F	0.317	0.320	0.333	0.330	0.022	0.59	0.87
Final BW, kg	127.04	132.18	129.69	126.74	2.41	0.76	0.11
Entire period							
Initial BW, kg	57.77	56.87	56.56	56.71	0.67	0.27	0.45
ADFI, kg	3.090	3.135	3.181	3.136	0.119	0.73	0.71
ADG, kg	0.991	1.078	1.047	1.002	0.034	0.99	0.04
G:F	0.320	0.344	0.332	0.322	0.011	0.85	0.13
Final BW, kg	127.04	132.18	129.69	126.74	2.41	0.76	0.11

[1]Data are means of 6 observations per treatment.

[2]Each period was 35 d.

RESULTS AND DISCUSSION

Pea Chips and Diet Composition

The concentration of CP, ADF, NDF, and P in pea chips was slightly greater than field peas (NRC, 1998). The reason for these differences may be that pea chips contain crushed peas and the smaller peas and hulls from peas that were dehulled during processing. Pea chips, therefore, do not necessarily contain the average field peas, which may explain the small differences in nutrient composition between pea chips and field peas. Pea chips used in this experiment contained less CP, ADF, and NDF than pea chips used by Igbasan and Gunther (1996), but the processing technologies that were used to generate the pea chips were different between the 2 experiments, which may explain these differences.

The protein in peas has a relatively high concentration of Lys and low concentration of Met, Cys, Thr, and Trp (Stein et al., 2004). Diets containing field peas, therefore, need to be fortified with crystalline Met, Thr, and Trp, whereas the concentration of crystalline Lys can be reduced if field peas are included in the diets. Although no previous research has been conducted with pea chips fed to pigs, we used these principles in formulating the pea chip diets for the current project, and AA analyses of the diets confirmed that the indispensable AA (Table 3) contents in all diets were relatively similar and close to expected values.

Pig Performance

All pigs stayed healthy during the experiment, and feed acceptance was not influenced by the inclusion of pea chips in the diets. There were no effects of dietary treatments on final BW and ADFI during the early finishing phase (Table 4). However, there was a quadratic response in ADG ($P = 0.08$) and G:F ($P = 0.05$) in the early finishing phase, with the greatest BW gain and BW gain efficiency observed in pigs fed the diet that 33.3% of the soybean meal was replaced by pea chips. There were no differences among treatments in final BW, ADG, ADFI, and G:F during the late finishing phase.

Moreover, for the entire experimental period, final BW, ADFI, and G:F were not different among treatments. This observation is in agreement with data showing that field peas can substitute for soybean meal in diets fed to growing-finishing pigs without influencing ADFI (Stein et al., 2006). Thus, it seems that pigs do not discriminate against diets containing field peas or pea chips. However, similar to the early finishing phase, pigs responded quadratically to the inclusion of pea chips into diets in ADG ($P = 0.04$), with the least BW gain observed in pigs fed the control diet. The quadratic increase in ADG of pigs fed the diets containing pea chip was not expected and is difficult to explain. The ADFI was not different among treatments; thus, the increased ADG was mainly caused by a better efficiency of pigs fed diets containing pea chips compared with pigs fed the control diet, although no statistically significant differences in G:F were observed. When including field peas in diets fed to growing-finishing pigs, no increase in ADG has been observed (Stein et al., 2004, 2006; Petersen and Spencer, 2006).

Carcass Composition and Quality

There were no differences in HCW, LM area, 10th-rib backfat, calculated lean meat percentage, marbling,

Table 5. Effects of replacing soybean meal by pea chips on carcass composition and quality[1]

	Soybean meal replacement, %					*P*-value	
Item	0.0	33.3	66.6	100.0	SEM	Linear	Quadratic
BW, kg	127.27	132.42	129.92	126.97	2.41	0.76	0.11
HCW, kg	97.61	100.80	97.16	95.98	1.79	0.30	0.24
Dressing, %	76.80	76.11	74.80	75.61	0.47	0.04	0.14
LM area, cm^2	53.80	49.90	51.40	52.70	2.41	0.87	0.31
10th-rib backfat, mm	25.00	31.00	24.00	25.00	2.40	0.62	0.35
Lean meat, %	53.58	50.28	53.17	53.52	1.34	0.66	0.20
Marbling[2]	2.67	1.75	2.17	2.33	0.40	0.75	0.20
LM, 45-min pH	6.35	6.24	6.17	6.23	0.07	0.19	0.24
LM, 24-h pH	5.59	5.45	5.43	5.53	0.07	0.51	0.13
Ham, 45-min pH	6.41	6.24	6.06	6.20	0.14	0.22	0.30
Ham, 24-h pH	5.66	5.51	5.51	5.69	0.11	0.83	0.14
Shoulder, 45-min pH	6.25	6.21	6.19	6.17	0.09	0.53	0.90
Shoulder, 24-h pH	5.89	5.71	5.64	5.77	0.08	0.25	0.08
24-h drip loss, %	1.59	2.46	3.45	2.67	0.60	0.14	0.19
10-d purge loss, %	4.94	4.76	4.87	4.98	1.10	0.96	0.89

[1]Data are means of 6 observations per treatment.

[2]National Pork Producers Council (NPPC, 1999).

drip loss, and purge loss among treatments. However, dressing percentage was less in pigs fed diets containing pea chips (linear, $P = 0.04$; Table 5). Pea chips inclusion did not influence pH at 45 min and 24 h that were measured in LM and ham. In addition, the 45-min shoulder pH was not different among treatments, but there was a tendency (quadratic, $P = 0.08$) for a reduction in 24-h shoulder pH as pea chips replaced soybean meal in the diets, with the lowest pH observed for the pigs that received diets, in which 66.6% of the soybean meal was replaced by pea chips. No negative effects on carcass composition and pH measurements in pigs fed diets containing pea chips is in agreement with data obtained in pigs fed field peas (Stein et al., 2006) and shows that inclusion of pea chips in diets fed to growing-finishing pigs does not change carcass composition. A similar observation was reported when field peas were fed to heifers or steers (Maddock Carlin et al., 2006; Andersen et al., 2007; Magolski et al., 2008). Nevertheless, the reduced dressing percentage observed in pigs fed the pea chip diets offsets the advantage of the increased ADG.

Subjective LM color score was reduced (quadratic, $P = 0.03$) as pea chips replaced soybean meal in the diets with the smallest value (lightest color) obtained in pigs fed diets, in which pea chips replaced 33.3% of the soybean meal in the diets (Table 6). The LM L* and a* colors and the color saturation were not influenced by the inclusion of pea chips in the diets, but LM b* values and hue angle tended to be greater (quadratic, $P = 0.09$ and 0.10, respectively) when pea chips replaced soybean meal in the diets, with the diet that pea chips replaced 66.6% of the soybean meal having the greatest values. However, values for LM JCSS were less (quadratic, $P = 0.05$) when pea chips were included in the diets, with the least value (lightest color) obtained in pigs fed the diets in which 33.3% of the soybean meal was replaced by pea chips. Values for ham a* and color saturation increased (linear, $P = 0.02$) and L* values and hue angle also increased (quadratic, $P = 0.04$ and 0.05, respectively) as pea chips replaced soybean meal in the diets. There was, also, a trend for greater b* values in hams (quadratic, $P = 0.07$) as pea chips replaced soybean meal in the diets. In contrast, none of the color values of the shoulder or external fat were influenced by treatment. The reduced subjective color scores in loins from pigs fed diets containing pea chips and the reduced JCSS indicate that loin and pork chops from pigs fed pea chips have lighter color. These observations were confirmed by the tendencies for increased values for b* and hue angle in loins from pigs fed the pea chip diets. Color scores for the ham also confirm that inclusion of pea chips in the diets increases measures for lighter color. However, values for a* and color saturation in the ham also increased as pea chips were included in the diets, which indicates that pea chips also make hams appear more red. The reason for the reduced color scores of the loins in pigs fed pea chips may be due to the decreased concentrations of magnesium in peas. In other research, magnesium aspartate dietary supplementation has shown to reduce the incidence of PSE pork (D'Souza et al., 1998) by reducing plasma cortisol and catecholamine concentrations (Niemack et al., 1979; Kietzmann and Jablonski, 1985). The magnesium concentration in soybean meal is greater (0.3 vs. 0.12%, DM basis; NRC, 1998) than field peas and may have been a factor in the different color scores we observed in the LM between the treatments.

Palatability

Cook loss percentage, shear force, juiciness, and pork flavor scores were not different among treatments (Table 7). However, tenderness decreased (linear, $P = 0.04$)

Table 6. Effects of replacing soybean meal by pea chips on carcass and fat coloration[1,2]

	Soybean meal replacement, %					*P*-value	
Item	0.0	33.3	66.6	100.0	SEM	Linear	Quadratic
LM							
Color[3]	2.75	2.00	2.42	2.50	0.18	0.68	0.03
L*	53.75	57.94	57.45	56.57	1.62	0.29	0.14
a*	19.23	19.81	20.21	20.00	0.49	0.23	0.43
b*	4.62	5.92	6.25	5.71	0.51	0.14	0.09
Color saturation	19.80	20.70	21.19	20.81	0.55	0.17	0.26
Hue angle	13.47	16.61	17.10	15.82	1.26	0.20	0.10
JCSS[4]	3.92	2.83	3.42	3.33	0.23	0.27	0.05
Ham							
L*	50.68	57.75	54.12	53.27	1.76	0.61	0.04
a*	20.38	20.71	20.89	21.56	0.33	0.02	0.61
b*	4.23	6.13	5.59	5.01	0.62	0.53	0.07
Color saturation	20.85	21.64	21.63	22.19	0.36	0.02	0.74
Hue angle	11.77	16.44	14.99	12.97	1.60	0.77	0.05
Shoulder							
L*	47.18	46.39	47.74	45.00	1.51	0.45	0.53
a*	24.03	25.01	24.19	24.31	0.72	0.99	0.56
b*	6.04	6.51	6.95	5.39	0.72	0.64	0.17
Color saturation	24.81	25.91	25.19	24.91	0.84	0.91	0.43
Hue angle	13.92	14.20	15.95	12.49	1.25	0.66	0.16
Fat[5]							
L*	78.38	78.73	77.41	78.18	0.71	0.56	0.77
a*	10.93	10.67	11.67	11.37	0.46	0.28	0.96
b*	0.79	0.59	0.87	0.92	0.27	0.59	0.66

[1]Data are means of 6 observations per treatment.

[2]Color measurements: L* = lightness, white = 100, black = 0; a* = redness, positive a* = red, negative a* = green; b* = yellowness, positive b* = yellow, negative b* = blue; color saturation = $(a^*)^2 + (b^*)^2$, where a greater number is more vivid; hue angle = arctangent (b*/a*) × (360°/2 × 3.14) expressed in degrees, where 0° is true red and 90° is true yellow.

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

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

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

as pea chips replaced soybean meal in the diets. The linear reduction in taste panel tenderness scores as pea chip inclusion in the diets increased was not expected because no differences in tenderness were observed by Stein et al. (2006) when field peas were included in diets fed to pigs. It has also been reported that when field peas are fed to beef cattle, tenderness of beef loin increases (Maddock Carlin et al., 2006; Andersen et al., 2007; Hinkle et al., 2010). To our knowledge, tenderness values have not been previously measured in any species fed pea chip diets, but results from the taste panel indicate that pork chops become slightly tougher as pea chips are included in the diets, although this observation was not supported by differences in shear force values.

One possible explanation for the reduced tenderness in pork chops from pigs fed pea chips, but not from pigs fed field peas, may be that the change in tenderness is caused by specific components in the peas that are present in greater concentrations in pea chips than

Table 7. Effects of replacing soybean meal with pea chips on the palatability of pork chops[1]

	Soybean meal replacement, %					*P*-value	
Item	0.0	33.3	66.6	100.0	SEM	Linear	Quadratic
Cook loss, %	16.59	18.08	21.02	19.05	1.30	0.10	0.20
Shear force, kg	2.98	3.20	3.25	3.17	0.21	0.51	0.50
Pork chop palatability							
Tenderness[2]	5.98	5.74	5.23	5.23	0.27	0.04	0.67
Juiciness[3]	5.78	5.80	5.62	5.62	0.25	0.56	0.93
Pork flavor[4]	5.70	5.48	5.77	5.43	0.18	0.53	0.75

[1]Data are means of 6 observations per treatment.

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

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

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

intact field peas. There is, therefore, a need to conduct research with different components of field peas to address this question.

Conclusions

Pea chips have a chemical composition that is close to that of field peas, although the concentration of CP, ADF, and NDF is slightly greater in pea chips compared with field peas. Results of the present experiment indicate that soybean meal in diets fed to growing-finishing pigs may be replaced by pea chips without negatively influencing growth performance or carcass composition. However, pigs fed pea chips will have pork chops and hams that are lighter, and chops may be less tender if pigs are fed pea chips rather than corn and soybean meal.

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