Effects of Pelleting Growing-Finishing Swine Diets on Growth, Carcass, and Bacon Characteristics

Dustin D. Boler, Martin F. Overholt, Jessica E. Lowell, Anna C. Dilger, and Hans H. Stein
Department of Animal Sciences
University of Illinois, Urbana, IL 61801
Phone: (217) 300-4847
dboler2@illinois.edu

Summary

A total of 192 barrows and gilts were allotted to two blocks based on age at the date of allocation. Pens of pigs were assigned to one of four dietary treatments: 1) meal form with 0% DDGS, 2) meal form with 30% DDGS, 3) pelleted form with 0% DDGS, or 4) pelleted form with 30% DDGS. Pigs were fed for 91 d and subsequently slaughtered at the University of Illinois Meat Science Laboratory. Over the 91-d feeding period, pigs fed the pelleted diet grew 3.1% faster and were at least 4% more efficient than pigs fed the meal diets. Pigs fed the pelleted diet had less full gastrointestinal weight as percentage of live weight when compared with pigs fed the meal diet. Emptied intestinal weights were not different between the two treatment groups. Pigs fed the pelleted diet had lesser gut fill (full gastrointestinal weight—emptied intestinal mass) than pigs fed the meal diet. Pigs fed the pelleted diet had greater ulceration scores compared with pigs fed the meal diet, but both treatments had stomachs that would be considered generally healthy. Neither feeding program would result in stomachs that would negatively affect pig drop value (value of the non-carcass components). Iodine values of belly fat from pellet fed pigs were 4.3% greater than meal fed pigs, but the increase in iodine value did not decrease commercial bacon slicing yields. Bellies from pellet fed pigs yielded 1.16 slices per kg less bacon than bellies from meal fed pigs. Producers can take advantage of the growth performance benefits of feeding a pelleted diet without reducing total drop value or commercial bacon slicing yield.

Introduction

Pelleting swine diets is a technology used by the feed milling industry where a meal diet is subjected to heat and (or) moisture, then pressed through a die to agglomerate smaller particles into a larger composite. In doing so, feed handling issues such as flowability and bridging of finely ground diets in bulk bins and delivery systems are ameliorated. Pelleting also reduces segregation of feedstuffs, increases bulk density, and reduces dustiness of the diet. In addition to these benefits, feeding a pelleted diet improves growth performance and feed efficiency of growing-finishing pigs. Feeding a pelleted diet for 81 d resulted in a 3% increase ($P = 0.03$) in growth rate and a 6% increase ($P < 0.01$) in feed efficiency when compared with pigs fed a meal diet (Nemechek et al., 2013). Wondra et al. (1995) reported that feed efficiency was increased and feed intake was reduced by feeding a pelleted diet, with a greater reduction in feed intake as particle size was reduced in pelleted diets than in meal diets. These improvements can be attributed to the compounding effects of reduced particle size and pelleting on nutrient digestibility. Digestible and metabolizable energy increased linearly ($P < 0.05$) as corn particle size decreased from 865 μm to 339 μm (Rojas and Stein, 2015). In another report, reducing dietary particle size from 1000 μm to 400 μm increased nutrient digestibility and in turn increased feed efficiency of meal fed pigs by 7% (Wondra et al., 1995). The challenge with reducing dietary particle size is the accompanied increase in stomach lesions and esophagogastric ulcers (Mahan et al., 1966). Additionally, feeding a pelleted diet increased the occurrence of stomach health issues of growing-finishing pigs (De Jong et al., 2015).

Feeding pelleted diets increased linoleic acid by 10.2% and linolenic by 7.8% (Nemechek et al., 2013). At the same time, palmitic acid was decreased by 2.6% and stearic acid by 2.2% (Nemechek et al., 2013). These changes resulted in 4.5% increase in calculated iodine value of belly fat from pigs fed a pelleted diet compared with pigs fed a meal diet (Matthews et al., 2014). Iodine value is considered an indication of fat quality. However, iodine value is poorly correlated with commercial bacon slicing yields ($r = -0.15$, $P < 0.05$; Kyle et al., 2014). It is not known if the observed increase in iodine value of fat from pellet fed pigs will have detrimental effects on commercial bacon slicing yields. Therefore, the objective of this experiment was to determine if the increased iodine value of belly fat of pigs fed a pelleted diet results in decreased commercial bacon slicing yields.

Table 1. Ingredient composition of experimental diets, as-fed basis.

	Phase 1: d 0 - d 35				Phase 2: d 36 - d 70				Phase 3: d 71 - 91			
	Meal		Pellet		Meal		Pellet		Meal		Pellets	
Ingredient, %	0%	30%	0%	30%	0%	30%	0%	30%	0%	30%	0%	30%
Corn	72.0	47.0	72.0	47.0	78.0	55.0	78.0	55.0	81.0	59.0	81.0	59.0
SBM, 48%	22.0	17.3	22.0	17.3	18.2	12.0	18.2	12.0	16.0	8.0	16.0	8.0
DDGS	0.0	30.0	0.0	30.0	0.0	30.0	0.0	30.0	0.0	30.0	0.0	30.0
C.W. Grease	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Limestone	0.85	1.15	0.85	1.15	0.80	1.10	0.80	1.10	0.70	1.05	0.70	1.05
Dicalcium P	1.1	0.6	1.1	0.6	0.8	0.35	0.8	0.35	0.7	0.2	0.7	0.2
Lys HCl	0.34	0.35	0.34	0.35	0.21	0.27	0.21	0.27	0.13	0.25	0.13	0.25
DL-Met	0.04	-	0.04	-	-	-	-	-	-	-	-	-
Thr	0.09	-	0.09	-	0.03	-	0.03	-	-	-	-	-
Salt	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Swine TM[1]	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vit. ADEK[1]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Tylan	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-

1 Provided the following quantities of vitamins and micro-minerals per kilogram of complete diet: Vitamin A as retinyl acetate, 11,136 IU; dimethylprimidinol bisulfite, 1.42 mg; thiamin as thiamine mononitrate, 0.24 mg; riboflavin, 6.59 mg; pyridoxine as pyridoxine hydrochloride,0.24 mg; vitamin B12, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.5 mg; niacin, 44.1 mg; folic acid, 1.59 mg; biotin, 0.44 mg; Cu, 20 mg as copper sulfate and copper chloride; Fe, 126 mg as ferrous sulfate; I, 1.26 mg as ethylenediamine dihydriodide; Mn, 60.2 mg as manganese sulfate; Se, 0.3 mg as sodium selenite and selenium yeast; and Zn, 125.1 mg as zinc sulfate.

Experimental Procedures

Experimental Design and Dietary Treatments

A total of 192 barrows and gilts (initial BW = 25.75 kg) were used in 2 blocks based on age. Each block consisted of 6 replications per treatment. Each replication included 4 pens with each pen housing 2 barrows and 2 gilts for a total of 24 pens per block (48 pens total). Pens of pigs were assigned to 1 of 4 dietary treatments: 1) meal form with 0% DDGS, 2) meal form with 30% DDGS, 3) pelleted form with 0% DDGS, or 4) pelleted form with 30% DDGS. All diets were formulated to meet current estimates for nutrient requirements for growing-finishing pigs (NRC, 2012).

A 3-phase, 91-d feeding program (Tables 1 & 2) was used with grower diets fed from d 0 to 35, early finisher diets fed from d 36 to 70, and late finisher diets fed from d 71 to 91. All diets were formulated based on values for the standardized total tract digestibility of P, standardized ileal digestibility (**SID**) of amino acids (**AA**), and net energy (NRC, 2012). Pigs were weighed at the beginning of the experiment and again at the end of each of the 3 feeding phases (d 35, 70, 91). Daily feed allotments were recorded,

Table 2. Calculated nutritional composition of experimental diets, as-fed basis.

	Phase 1: d 0 - d 35				Phase 2: d 36 - d 70				Phase 3: d 71 - 91			
Calculated	Meal		Pellet		Meal		Pellet		Meal		Pellets	
analysis	0%	30%	0%	30%	0%	30%	0%	30%	0%	30%	0%	30%
NE, kcal/kg	2,490	2,427	2,490	2,427	2,528	2,468	2,528	2,468	2,548	2,497	2,548	2,497
CP, %	16.43	20.34	16.43	20.34	15.06	18.44	15.06	18.44	14.3	16.88	14.3	16.88
Ca, %	0.67	0.66	0.67	0.66	0.56	0.56	0.56	0.56	0.50	0.49	0.50	0.49
P[1], %	0.31	0.31	0.31	0.31	0.25	0.26	0.25	0.26	0.23	0.23	0.23	0.23
Amino acids[2], %												
Arg	0.95	1.01	0.95	1.01	0.84	0.86	0.84	0.86	0.78	0.75	0.78	0.75
His	0.40	0.47	0.40	0.47	0.36	0.42	0.36	0.42	0.35	0.38	0.35	0.38
Ile	0.58	0.68	0.58	0.68	0.52	0.6	0.52	0.6	0.49	0.53	0.49	0.53
Leu	1.30	1.76	1.30	1.76	1.23	1.66	1.23	1.66	1.19	1.57	1.19	1.57
Lys	0.98	0.98	0.98	0.98	0.79	0.79	0.79	0.79	0.67	0.68	0.67	0.68
Met	0.28	0.31	0.28	0.31	0.23	0.29	0.23	0.29	0.22	0.28	0.22	0.28
Met + Cys	0.55	0.60	0.55	0.60	0.49	0.57	0.49	0.57	0.47	0.53	0.47	0.53
Phe	0.70	0.85	0.70	0.85	0.64	0.77	0.64	0.77	0.61	0.70	0.61	0.70
Thr	0.59	0.59	0.59	0.59	0.49	0.52	0.49	0.52	0.43	0.46	0.43	0.46
Trp	0.17	0.17	0.17	0.17	0.15	0.14	0.15	0.14	0.13	0.12	0.13	0.12
Val	0.65	0.79	0.65	0.79	0.6	0.72	0.6	0.72	0.56	0.65	0.56	0.65

1 Standadardized total tract digestible P.
2 Amino acids are indicated as standardized ileal digestible AA.

Table 3. Effects of pelleting and distillers dried grains with solubles (DDGS) on growth characteristics of barrows and gilts.

Item	Diet Form × DDGS Inclusion[1] Meal - 0% DDGS	Meal - 30% DDGS	Pelleted - 0% DDGS	Pelleted - 30% DDGS	SEM	*P*-Values Diet Form	DDGS	Diet Form × DDGS
Pen[1], n	12	12	12	12				
Phase 1 (Day 0-35)								
Beginning live weight (day 0), kg	25.79	25.78	25.68	25.73	0.66	0.07	0.68	0.41
Day 35 live weight, kg	57.66	56.60	58.61	56.72	0.97	0.28	< 0.01	0.41
ADG (0-35), kg/d	0.91	0.88	0.94	0.89	0.02	0.21	0.01	0.34
ADFI (0-35), kg/d	1.91	1.87	1.92	1.83	0.03	0.51	0.03	0.42
G:F (0-35)	0.474	0.472	0.491	0.485	0.007	< 0.01	0.44	0.68
Phase 2 (Day 36-70)								
Day 70 live weight, kg	91.53	91.19	94.13	91.39	1.31	0.12	0.09	0.18
ADG (70), kg/d	0.97	0.99	1.01	1.01	0.01	0.03	0.50	0.36
ADFI (70), kg/d	2.72[a]	2.86[b]	2.80[ab]	2.71[a]	0.05	0.40	0.45	< 0.01
G:F (70)	0.357[ab]	0.347[a]	0.363[bc]	0.374[c]	0.005	< 0.01	0.90	0.03
Phase 3 (Day 71 -91)								
Day 91 live weight, kg	111.19	111.60	115.31	113.38	1.37	< 0.01	0.37	0.17
ADG (91), kg/d	0.92	0.97	1.00	1.01	0.03	0.01	0.18	0.46
ADFI (91), kg/d	3.11[a]	3.37[b]	3.14[a]	3.15[a]	0.06	0.07	< 0.01	0.02
G:F (91)	0.297	0.288	0.318	0.321	0.007	< 0.0001	0.58	0.36
Overall (Day 0-91)								
Overall ADG, kg/d	0.94	0.94	0.98	0.96	0.01	< 0.01	0.46	0.11
Overall ADFI, kg/d	2.58[a]	2.70[b]	2.62[ab]	2.56[a]	0.04	0.11	0.25	< 0.01
Overall G:F	0.370[b]	0.360[a]	0.383[c]	0.386[c]	0.005	< 0.0001	0.27	0.03

1 Each pen of pigs housed 2 barrows and 2 gilts.

and data were summarized to calculate ADG, ADFI, and G: F for each pen during each phase of the feeding period. The heaviest barrow and gilt in each pen were harvested on d 92 and the remaining barrows and gilts were slaughtered 2 d later to determine hot carcass weight (HCW), carcass yield, carcass characteristics, meat quality, and fat quality. Mass of the gastrointestinal (GI) tract was determined using the heaviest barrow and gilt from each pen.

Slaughter Procedures and Evisceration

Pigs were transported to the University of Illinois Meat Science Laboratory (Urbana, IL) and held for approximately 16 h in lairage prior to slaughter. Pigs were weighed immediately prior to slaughter to determine ending live weight. Pigs were immobilized via head-to-heart electrical stunning followed by exsanguination. Full GI tract and GI tract component weights were recorded immediately following evisceration for the heaviest barrow and gilt from each pen. Each section of the GI tract was rinsed with water to remove all digestive and fecal material. Mesenteric tissue surrounding the GI tract was removed and weighed separately. Gut fill was calculated as the difference between the full GI tract and the cleaned, separated components. GI tract mass was calculated in terms of absolute mass and as a percentage of ending live weight. The stomach from the heaviest barrow and heaviest gilt in each pen were identified, frozen, and stored for later ulcer evaluation.

Table 4. Effects of pelleting and distillers dried grains with solubles (DDGS) on carcass characteristics of barrows and gilts.

Item	Diet Form Meal	Pellet	SEM	DDGS 0%	30%	SEM	*P*-Values Diet Form	DDGS	Diet × DDGS
Pen[1], n	24	24		24	24				
Final farm wt, kg	111.40	114.34	1.24	113.25	112.49	1.24	0.002	0.37	0.17
Ending live wt, kg	110.50	113.06	1.30	112.65	110.91	1.30	< 0.01	0.06	0.11
HCW, kg	86.34	88.84	1.12	88.65	86.54	1.12	0.01	0.01	0.17
Carcass yield, %	78.11	78.56	0.14	78.66	78.00	0.14	0.02	< 0.001	0.78
Loin eye area, cm^2	49.49	49.65	0.75	50.41	48.73	0.75	0.84	0.04	0.71
Fat depth (10th rib), cm	1.63	1.80	0.04	1.74	1.70	0.04	0.01	0.40	0.08
Estimated carcass lean[2], %	56.70	54.91	0.59	56.25	55.36	0.59	0.04	0.30	0.10

1 Each pen of pigs housed 2 barrows and 2 gilts.
2 Estimated carcass lean = [(8.588 + (0.465 * HCW, lb) - (21.896 * 10th rib fat depth, in) + (3.005 * 10th rib LEA, in^2))/ HCW] * 100.

Table 5. Effects of pelleting and distillers dried grains with solubles (DDGS) on visceral weights and percentage of ending live weight of barrows and gilts.

	Diet Form			DDGS			*P*-Values		
Item	**Meal**	**Pellet**	**SEM**	**0%**	**30%**	**SEM**	**Diet Form**	**DDGS**	**Diet Form × DDGS**
Pen[1], n	24	24		24	24				
Full GI tract, kg	7.65	7.42	0.11	7.37	7.70	0.11	0.14	0.03	0.08
Full GI tract, %	6.79	6.46	0.11	6.41	6.84	0.11	0.03	< 0.01	0.18
Esophagus, kg	0.07	0.08	0.002	0.07	0.08	0.002	0.02	0.23	0.01
Esophagus, %	0.06	0.07	0.002	0.06	0.07	0.002	0.08	0.05	0.02
Stomach, kg	0.63	0.61	0.01	0.61	0.62	0.01	0.25	0.36	0.66
Stomach, %	0.55	0.53	0.01	0.53	0.55	0.01	0.07	0.10	0.51
Small intestine, kg	1.50	1.53	0.03	1.51	1.52	0.03	0.57	0.86	0.37
Small intestine, %	1.34	1.33	0.03	1.32	1.35	0.03	0.87	0.39	0.27
Large intestine, kg	1.73	1.72	0.03	1.64	1.80	0.03	0.81	< 0.01	0.17
Large intestine, %	1.54	1.49	0.03	1.43	1.60	0.03	0.31	< 0.01	0.27
Intestinal mass[2], kg	3.24	3.25	0.05	3.17	3.33	0.06	0.94	0.02	0.42
Intestinal mass, %	2.88	2.83	0.04	2.76	2.95	0.04	0.41	< 0.01	0.62
Mesenteric fat, kg	1.68	1.83	0.05	1.77	1.74	0.05	0.02	0.75	0.06
Mesenteric fat, %	1.49	1.59	0.04	1.53	1.55	0.04	0.07	0.86	0.08
Gut fill[3], kg	2.07	1.66	0.07	1.75	1.98	0.07	< 0.01	0.02	0.19
Gut fill, %	1.84	1.45	0.07	1.53	1.77	0.07	< 0.01	0.01	0.24
Ulceration score[4]	1.27	1.79	0.12	1.40	1.67	0.12	< 0.01	0.10	0.44

1 Each pen of pigs housed 2 barrows and 2 gilts. Represents the mean of the heaviest barrow and heaviest gilt from each pen.
2 Intestinal mass = esophagus + stomach + small intestine + large intestine.
3 Gut fill = full GI tract - (esophagus + stomach + small intestine + large intestine + mesenteric fat).
4 Ulceration scores were rated on a 10 point scale where 0 represents a normal stomach with no evidence of ulceration and 10 represented a bleeding ulcer that might later cause the pig's death.

Stomach Morphology Evaluation

Stomachs were allowed to thaw at 4°C for 72 h prior to evaluation. Evaluation of ulceration and parakeratosis in the pars oesophagea region of the stomach was conducted by 3 trained panelists, using a 10-point scale, according to the protocol described by Nielsen and Ingvartsen (2000). Zero represented a normal stomach with no evidence of ulceration and 10 represented a bleeding ulcer that might later cause the pig's death. Scores were averaged across the 3 evaluators for each pig. The average score was reported as the ulceration score.

Carcass Characteristics and Fresh Loin Quality

Carcasses were weighed immediately prior to entering the cooler to determine HCW. Carcass yield was calculated as the ratio of HCW and ending live weight. Carcasses were chilled at 4°C for approximately 24 h. Carcass characteristics and fresh loin quality were determined on the left side of each carcass. Carcasses were cut between the 10th and 11th rib interface to expose the longissimus muscle (**LM**). Tenth rib backfat was measured at ¾ the distance of the LM from the dorsal process of the vertebral column. Loin eye area (**LEA**) was measured by tracing the surface of the LM on double matted acetate paper. Longissimus muscle tracings were measured in duplicate using a digitizer tablet (Wacom, Vancouver, WA) and Adobe Photoshop CS6 and the average of the 2 measurements were reported. Water-holding capacity, proximate composition, and Warner-Bratzler shear force were determined on an excised portion of the longissimus muscle cut posterior to the 10th rib. Color, marbling, firmness, and ultimate pH were determined on the cut surface anterior to the 10th rib after a 20-min bloom period by trained individuals.

Belly Characteristics

Bellies were fabricated to meet the specifications of an Institutional Meat Purchase Specifications (**IMPS**) #408 belly and then skinned to the meet the specifications of an IMPS #409 belly. Bellies were transported to a commercial bacon processing facility and were processed at the facility in the same manner as described by Tavárez et al. (2014). Bellies were processed using standard operating protocols of the commercial bacon processing facility. In short, bellies were pumped using a cure solution that delivered a target of 1.50% sodium chloride at a 13% pump uptake. Bellies were then cooked and smoked using a step-up cooking cycle for approximately 4 h with bellies reaching an internal temperature of 53°C. Bellies were frozen to –6°C, pressed, and sliced. Unusable ends and incomplete slices were sorted and removed by trained plant personnel. Sliced bellies were boxed individually maintaining anatomical

Table 6. Effects of pelleting and distillers dried grains with solubles (DDGS) on meat quality of barrows and gilts.

	Diet Form			DDGS			*P*-Values		
Item	Meal	Pellet	SEM	0%	30%	SEM	Diet Form	DDGS	Diet Form × DDGS
Pen[1], n	24	24		24	24				
Subjective evaluations[2]									
Color	1.93	1.80	0.05	1.87	1.86	0.05	0.07	0.89	0.48
Marbling	1.32	1.28	0.06	1.31	1.30	0.06	0.70	0.90	0.64
Firmness	1.46	1.55	0.08	1.51	1.49	0.08	0.40	0.83	0.89
Objective color[3]									
L*	50.66	51.32	0.40	51.34	50.63	0.40	0.19	0.16	0.79
a*	8.59	8.34	0.16	8.55	8.38	0.16	0.23	0.38	0.31
b*	4.13	4.16	0.19	4.32	3.97	0.19	0.92	0.15	0.64
Ultimate pH	5.57	5.58	0.01	5.58	5.58	0.01	0.38	0.85	0.61
Drip loss, %	5.67	5.47	0.26	5.63	5.51	0.26	0.55	0.70	0.90
Cook loss, %	24.90	24.51	0.45	24.45	24.96	0.45	0.47	0.35	0.57
Shear force[4], kg	3.21	3.10	0.07	3.13	3.18	0.07	0.27	0.62	0.57

1 Each pen of pigs housed 2 barrows and 2 gilts.
2 L* = lightness; a* = redness; b* = yellowness.
3 Subjective evaluations based on standards provided by the National Pork Producers Council (Des Moines, IA).
4 Warner-Bratzler shear force.

orientation (blade to flank end) and transported back to the Meat Science Laboratory at the University of Illinois for further evaluation. Sliced weights of each processed belly were collected to determine a bacon slicing yield. Slices were counted to determine the number of saleable slices. Processed bellies were then separated into 5 equal portions based on anatomical orientation (zones A, B, C, D, and E) with zone A representing the anterior (blade) end and zone E representing the posterior (flank) end. Moisture and lipid content was determined as the pooled average of 2 slices from the approximate center of each zone. Image analysis on 1 slice from the approximate center of zones A, C, and E was used to determine lean-to-fat ratios of each processed belly.

Statistical Analyses

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC, USA) as a 2 x 2 factorial arrangement of treatments in a randomized complete block design. Pen (n = 48) was the experimental unit for all dependent variables. Fixed effects were diet form (meal or pellet), DDGS inclusion (0% or 30%), and the interaction between diet form and DDGS. Block and replication nested within block were random variables.

Results and Discussion

Over the 91-d feeding period, pigs fed the pelleted diet (0.97 kg/d) grew 3.1% faster ($P < 0.01$) than pigs fed the meal diet (0.94 kg/d; Table 3). There were no differences in ADFI between pellet fed pigs fed either 0 or 30% DDGS. However, the meal fed pigs fed 30% DDGS consumed 0.12 kg/d more feed than the meal fed pigs fed 0% DDGS. This resulted in pellet fed pigs, regardless of DDGS inclusion, being 4% more efficient ($P < 0.0001$) than the meal fed pigs fed 0% DDGS and 6.7% more efficient than the meal fed pigs fed 30% DDGS. Pigs fed the meal diet with 0% DDGS also were 2.7% more efficient ($P = 0.02$) than pigs fed the meal diet with 30% DDGS.

Table 7. Effects of pelleting and distillers dried grains with solubles (DDGS) on fresh belly characteristics of barrows and gilts.

	Diet Form			DDGS			*P*-Values		
Item	Meal	Pellet	SEM	0%	30%	SEM	Diet Form	DDGS	Diet Form × DDGS
Pen[1], n	24	24		24	24				
Belly wt (IMPS # 408), kg	6.39	6.73	0.13	6.62	6.49	0.13	< 0.001	0.13	0.99
Belly wt, % chilled side wt	15.09	15.21	0.18	15.31	14.98	0.18	0.55	0.11	0.68
Length, cm	64.55	64.96	0.36	64.93	64.58	0.36	0.26	0.33	0.46
Width, cm	28.06	28.45	0.26	28.19	28.42	0.26	0.11	0.17	0.72
Average thickness[2], cm	3.58	3.66	0.05	3.78	3.46	0.05	0.12	< 0.0001	0.48
Flop distance, cm	11.64	10.85	0.77	13.73	8.76	0.77	0.44	< 0.0001	0.76
Thaw loss, %	1.63	1.57	0.07	1.61	1.59	0.07	0.55	0.80	0.13

1 Each pen of pigs housed 2 barrows and 2 gilts.
2 Average thickness was calculated as the average of 8 locations (1 to 4 were from anterior to posterior position of dorsal edge of the belly; locations 5 to 8 were from the anterior to posterior position of the ventral edge of the belly).

Table 8. Effects of pelleting and distillers dried grains with solubles (DDGS) on fatty acid profiles of belly fat from barrows and gilts.

Item	Diet Form			DDGS			*P*-Values		
	Meal	Pellet	SEM	0%	30%	SEM	Diet Form	DDGS	Diet Form × DDGS
Pen[1], n	24	24		24	24				
C16:0, %	22.66	21.99	0.13	23.07	21.58	0.13	< 0.01	< 0.0001	0.76
C16:1, %	2.66	2.30	0.03	2.73	2.24	0.03	< 0.0001	< 0.0001	0.09
C18:0, %	9.66	9.67	0.09	10.09	9.24	0.09	0.94	< 0.0001	0.64
C18:1, %	43.55	41.92	0.16	44.41	41.05	0.16	< 0.0001	< 0.0001	0.99
C18:2n6, %	16.13	18.86	0.24	14.55	20.44	0.24	< 0.0001	< 0.0001	0.86
C18:3n6, %	0.03	0.02	0.003	0.02	0.03	0.003	0.09	< 0.01	0.98
C18:3n3, %	0.55	0.59	0.01	0.53	0.61	0.01	< 0.01	< 0.0001	0.13
C20:1n9, %	0.77	0.76	0.01	0.77	0.75	0.01	0.75	0.09	0.07
Iodine value[2]	70.03	73.11	0.35	68.02	75.11	0.35	< 0.0001	< 0.0001	0.67

[1] Each pen of pigs housed 2 barrows and 2 gilts.
[2] Iodine value = C16:1 (0.95) + C18:1 (0.86) + C18:2 (1.732) + C18:3 (2.616) + C20:1 (0.785) + C22:1 (0.723), AOCS (1998).

There were no interactions ($P > 0.05$) between diet form and DDGS inclusion for carcass characteristics (Table 4). In general, there are few differences in carcass characteristics between meal and pellet fed pigs in the literature (Wondra et al., 1995; Myers et al., 2012, Nemechek et al., 2013). Unlike previous reports, pellet fed pigs in this experiment were 2.3% heavier ($P < 0.01$) at slaughter, and produced carcasses that were 2.9% heavier ($P = 0.01$), 9.9% fatter ($P = 0.01$) at the 10th rib, and had 1.79 percentage unit less carcass lean than meal fed pigs. There were no differences ($P = 0.84$) in LEA between meal and pellet fed pigs. These observations indicate that protein deposition was not influenced by dietary treatment, but pigs fed the pelleted diets likely were able to absorb more energy, which resulted in the increased deposition of fat and reduced lean percentage.

There were no differences ($P \geq 0.25$) in stomach weight, small intestine weight, large intestine weight, or calculated intestinal mass between pelleted and meal fed pigs (Table 5). There were also no differences ($P = 0.41$) in the proportion of intestinal mass relative to ending live weight between pelleted and meal fed pigs. Similar to 10th rib fat thickness, pellet fed pigs had 0.15 kg more ($P = 0.02$) mesenteric fat than meal fed pigs, which further indicate that pellet fed pigs absorbed more energy than meal fed pigs. Pellet fed pigs also had 0.41 kg less ($P < 0.01$) gut fill than meal fed pigs, which is likely a result of increased dry matter and energy digestibility in the pellet fed pigs. The greater ($P = 0.02$) carcass yield of pellet fed pigs compared with meal fed pigs was likely due to the combination of less gut fill and increased fatness. As expected, stomach ulceration score was greater ($P < 0.01$) in pellet fed pigs (1.79) compared with meal fed pigs (1.27), but the magnitude of difference was small and the average score of each treatment group was less than 2 and therefore considered healthy.

Fresh loin quality did not differ ($P \geq 0.23$) between pellet and meal fed pigs (Table 6). However, subjective color tended ($P = 0.07$) to be less (lighter) in pellet fed

Table 9. Effects of pelleting and distillers dried grains with solubles (DDGS) on belly processing characteristics of barrows and gilts.

Item	Diet Form			DDGS			*P*-Values		
	Meal	Pellet	SEM	0%	30%	SEM	Diet Form	DDGS	Diet Form × DDGS
Pen[1], n	24	24		24	24				
Green weight (IMPS #409), kg	5.29	5.64	0.11	5.54	5.38	0.11	< 0.0001	0.04	0.87
Pumped wt, kg	6.15	6.54	0.13	6.40	6.28	0.13	<0.01	0.19	0.54
Pump uptake, %	16.15	16.08	0.12	15.47	16.76	0.12	0.67	< 0.0001	< 0.01
Cooked and pressed wt, kg	5.54	5.95	0.12	5.80	5.70	0.12	< 0.0001	0.25	0.76
Cooked yield, %	104.61	105.63	0.18	104.48	105.77	0.18	< 0.01	< 0.0001	0.40
Sliced weight, kg	4.93	5.31	0.10	5.17	5.06	0.10	< 0.0001	0.14	0.54
Slicing yield (green wt), %	93.14	94.28	0.56	93.38	94.04	0.56	0.16	0.41	0.26
Sliced yield (cooked weight), %	89.02	89.26	0.51	89.37	88.90	0.51	0.75	0.52	0.16
Number of slices	183.76	191.97	2.85	191.71	184.02	2.85	< 0.01	< 0.01	0.42
Slice wt, g	26.82	27.67	0.25	26.97	27.52	0.25	< 0.01	< 0.09	0.10
Slices per kg	37.36	36.20	0.33	37.15	36.41	0.33	< 0.01	< 0.08	0.06

[1] Each pen of pigs housed 2 barrows and 2 gilts.

pigs compared with meal fed pigs, but there were no differences in L^*, a^*, or b^* ($P \geq 0.19$). Bellies from pellet fed pigs (6.73 kg) were 0.34 kg heavier ($P < 0.001$) than bellies from meal fed pigs (6.39 kg), but when calculated as a percentage of ending live weight, were not different ($P = 0.55$, Table 7). Furthermore, no other fresh belly characteristic differed ($P \geq 0.11$) between pellet and meal fed pigs.

Palmitic acid (C 16:0) was 0.67 percentage units greater ($P < 0.01$) in meal fed pigs compared with pellet fed pigs (Table 8). Both essential fatty acids (C 18:2 and C 18:3) were greater ($P \leq 0.01$) in pellet fed pigs compared with meal fed pigs. This increase in essential fatty acid percentages led to a 4.3% increase in calculated iodine value of pellet fed pigs (73.11) compared with meal fed pigs (70.03).

An increased iodine value is often associated with poor fat quality because it results in bellies that are soft and potentially more difficult to slice (Stein and Shurson, 2009). However, bacon processing techniques (chilling, pressing, and trim specifications) used today are in some cases able to compensate for soft bellies and still manufacture bacon slices that meet the criteria of a #1 bacon slice. A bacon slice regarded as a #1 slice must have secondary lean (m. cutaneous trunci) that is greater than 50% of the length of the slice and the slice must not be less than 1.9 cm thick at its thinnest point (Person et al., 2005). Iodine value is poorly correlated with commercial bacon slicing yields (r = -0.15, $P < 0.05$; Kyle et al., 2014). For example, Tavárez et al. (2014) reported an 8.48 iodine value unit difference between barrows fed 0% and 30% DDGS, but no difference ($P > 0.05$) in commercial bacon slicing yields. At the same time, Kyle et al., 2014 reported a 3.03 iodine value unit difference between barrows and boars, which resulted in a 3.8% difference ($P < 0.05$) in commercial slicing yield. In the current experiment, initial green weight differences persisted throughout processing, but there were no differences ($P = 0.75$) in commercial bacon slicing yields between bacon from pellet fed pigs and meal fed pigs (Table 9). However, processed bellies from pellet fed pigs produced 1.16 fewer ($P < 0.01$) slices of bacon per kg of sliced belly weight than processed bellies from meal fed pigs.

Some bacon slicers rely on a push-feed mechanism where constant pressure against the blade from subsequent bellies is necessary to produce slices with uniform slice thicknesses. In this type of belly slicing system, it is possible that the softer fat associated with an increased iodine value may influence the integrity of the slice thickness even though it meets the criteria for #1 bacon slice. The reduction in slices/kg may not be a cause for concern when producing bacon for retail service where producers are paid on weight, but may be potentially detrimental to processors manufacturing bacon for food-service applications where bacon is sold by the slice.

References

AOCS. 1998. Official methods and recommended practices of the AOCS (5th ed.). Champaign, Illinois: American Oil Chemist Society.

De Jong, J. A., J. M. DeRouchey, M. D. Tokach, R. D. Goodband, S. S. Dritz, and M. Allerson. 2015. Evaluating strategic pellet feeding regimens on finishing pig performance, stomach morphology, and carcass characteristics. J. Anim. Sci. 93(Suppl. 2): 173 (Abstr.).

Kyle, J. M., B. M. Bohrer, A. L. Schroeder, R. J. Matulis, and D. D. Boler. 2014. Effects of immunological castration (Improvest) on further processed belly characteristics and commercial bacon slicing yields of finishing pigs. J. Anim. Sci. 92:4223-4233.

Mahan, D. C., R. A. Pickett, T. W. Perry, T. M. Curtain, W. R. Featherston, and W. M. Beeson. 1966. Influence of various nutritional factors and physical form of feed on esophagogastric ulcers in swine. J. Anim. Sci. 25: 1019-1023.

Matthews, N., L. Greiner, C. R. Neill, S. Jungst, B. Fields, R. C. Johnson, and A. Sosnicki. 2014. Effect of feed form (mash vs. pellets) and ractopamine on pork fat quality. J. Anim. Sci. 92: Suppl. 2, 148.

Myers, A. J., R. D. Goodband, M. D. Tokach, S. S. Dritz, J. M. DeRouchey, and J. L. Nelssen. 2013. The effects of diet form and feeder design on the growth performance of finishing pigs. J. Anim. Sci. 91: 3420-3428.

Nemechek, J., M. Tokach, J. DeRouchey, S. Dritz, R. Goodband, and J. Nelssen. 2013. Effects of diet form and fiber level before marketing on growth performance, carcass yield, and iodine value of finishing pigs. J. Anim. Sci. 91(Suppl. 2): 24 (Abstr.).

Nielsen, E.K. and Ingvartsen, K.L. 2000. Effect of cereal type, disintegration method and pelleting on stomach content, weight, and ulcers and performance of growing pigs. Livest. Prod. Sci. 66: 271-282.

Person, R. C., D. R. McKenna, D. B. Griffin, F. K. McKeith, J. A. Scanga, K. E. Belk, G. C. Smith, and J. W. Savell. 2005. Benchmarking value in the pork supply chain: Processing characteristics and consumer evaluations of pork bellies of different thicknesses when manufactured into bacon. Meat Sci. 70: 121-131.

Rojas, O. J. and H. H. Stein. 2015. Use of feed technology to improve the nutritional value of feed ingredients fed to pigs. J. Anim. Sci. 93(Suppl. 2): 61 (Abstr.).

Stein H. H. and G. C. Shurson. 2009. BOARD-INVITED REVIEW: The use and application of distillers dried grains with solubles in swine diets. J. Anim. Sci. 87: 1292-1303.

Tavárez, M. A., B. M. Bohrer, M. D. Asmus, A. L. Schroeder, R. J. Matulis, D. D. Boler, and A. C. Dilger. 2014. Effects of immunological castration and distiller's dried grains with solubles on carcass cutability and commercial bacon slicing yields of barrows slaughtered at two time points. J. Anim. Sci. 92: 3149-3160.

Wondra, K. J., J. D. Hancock, K. C. Behnke, R. H. Hines, and C. R. Stark. 1995. Effects of particle size and pelleting on growth performance nutrient digestibilty and stomach morphology in finishing pigs. J. Anim. Sci. 73: 757-763.