NON RUMINANT NUTRITION

The effect of feed form and delivery method on feed microbiology and growth performance in grow-finisher pigs

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Abstract

There is no generally accepted optimal feed form and delivery method for feeding finisher pigs. The objective of this study was to compare the effect of feed form (meal and pellet) and delivery method (liquid, dry, and wet/dry) on feed microbiology and growth, gain-to-feed ratio (G:F), and carcass quality of finisher pigs. Two batches of pigs were used, each with six pen replicates per treatment. In each batch 216 pigs (32.7 kg; $\pm$ 0.48 SE) housed in same-sex (entire male or female) pens of six pigs per pen were on treatment for ~62 d prior to slaughter. The experiment was a 2 $\times$ 3 factorial arrangement with two factors for diet form (meal and pellets) and three factors for feed delivery (dry, wet/dry, liquid). The treatments were 1) meal from dry feeder, 2) meal from wet/dry feeder, 3) meal from liquid system, 4) pellet from dry feeder, 5) pellet from wet/dry feeder, and 6) pellet from liquid system. Pig growth performance was determined, blood samples collected at slaughter for hematological analysis and microbiological and proximate analysis of feed performed. A significant feed form $\times$ delivery interaction was found for G:F. During the overall period G:F was 0.446, 0.433, 0.423, 0.474, 0.459, and 0.418 g/g (SE = 0.0080; $P < 0.01$) for treatments 1 through 6, respectively. When feed was pelleted, G:F was improved when feed delivery was dry or wet/dry compared to meal but when the delivery was liquid, pelleting did not affect G:F. There were no interactive effects for overall average daily gain (ADG). Overall ADG was 1,114 and 1,156 g/d (SE = 16.9; $P < 0.01$) for pigs fed diets in meal and pellet form, respectively and 1,080, 1,114, and 1,210 g/d (SE = 18.4; $P < 0.001$) for dry-, wet/dry-, and liquid-fed pigs, respectively. Carcass weight was 76.6 and 79.0 kg (SE = 0.55; $P < 0.001$) for pigs fed in meal and pellet form, respectively, while it was 74.7, 77.3, and 81.5 kg (SE = 0.60; $P < 0.001$) for pigs delivered dry, wet/dry, and liquid diets, respectively. Lactic acid bacteria ($P < 0.05$) and yeast ($P < 0.01$) counts in troughs were greater for the liquid than the dry diet in both meal and pelleted form. There was also evidence of lysine degradation in the liquid diet but this did not impact pig growth. Feeding the diet in pelleted vs. meal form led to lower hemoglobin and greater white blood cell and neutrophil counts ($P < 0.05$). To conclude, wet/dry feeding of a pelleted diet is recommended to maximize growth rate while optimizing G:F in grow-finisher pigs.

Key words: dry feed, fattener, liquid feed, meal, pellet, swine

Abbreviations

AOAC	Association of Official Analytical Chemists
D	depth
H	height
LAB	lactic acid bacteria
MRD	maximum recovery diluent
SID lysine	standardized ileal digestible lysine
W	width
WBC	white blood cells

Introduction

Pelleting improves nutrient digestibility, reduces feed wastage, and increases flow ability, thereby increasing pig growth and improving feed efficiency (Dinussan and Bolin, 1958; Seerley et al., 1962; Ball et al., 2015; Nemechek et al., 2015a). Pelleted diets may also be of better microbiological quality than meal, as evidenced by lower Enterobacteriaceae counts (Burns et al., 2015). Feed delivery methods can largely be classified as dry (delivered in meal or pelleted form without being mixed with water), wet/dry (dry feed delivered as meal or pellets with pigs able to add water to the feed via a nipple or button drinker in the trough), and liquid (feed delivered pre-mixed with water from computer-controlled valves). Increased growth has been reported with liquid feeding of grow-finisher (Stotfold Research Centre, 2005; Hurst et al., 2008) and weaned (Russell et al., 1996; l'Anson et al., 2012) pigs; however, work by our group found poorer feed efficiency when weaned pigs are liquid-fed (Lawlor et al., 2002). Wet/dry feeding of finisher pigs reportedly increases average daily feed intake (ADFI) and average daily gain (ADG) over dry feeding (Gonyou and Lou, 2000; Bergstrom et al., 2008). Contrary to this, Magowan et al. (2008) reported that dry feeding finisher pigs maximized ADG but concluded that the optimal feed delivery system may be dependent on the stage of pig growth. It has also been reported that wet/dry feeding results in fatter carcasses with lower carcass yield than dry feeding (Bergstrom et al., 2008) which may also be the case with liquid feeding. The aim of this study was to compare dry, wet/dry, and liquid feeding of the same diet in meal and pelleted form to grow-finisher pigs. It was hypothesized that liquid-fed grow-finisher pigs would have improved growth rates over dry- and wet/dry-fed pigs, but with poorer feed efficiency (calculated from the intake of dry feed at 87.7% DM) and that the feed efficiency of pigs fed pelleted diets would be better than those fed meal diets.

Materials and Methods**Ethical approval**

Ethical approval for this study was granted by the Teagasc Animal Ethics Committee (approval no. TAEC 107/2015). The experiment was conducted in accordance with Irish legislation (SI no. 543/2012) and the EU Directive 2010/63/EU for animal experimentation.

Experimental design

The study comprised two batches of pigs, each comprising six pen replicates per treatment and fed the experimental diets for 64 d. A total of 432 Danavil Duroc × (Large White × Landrace) pigs (216 pigs per batch) penned in same-sex pens of 6 pigs per pen with a starting weight of ~32.7 kg were used in the experiment. Feed form and delivery methods were compared in

a 2 × 3 factorial arrangement, with two factors for feed form (meal and pellets) and three factors for feed delivery (dry, wet/dry, and liquid). Pig pens were blocked on weight and sex. Pens were randomly assigned to one of six dietary treatments in a completely randomized block design as follows: 1) dry meal diet, 2) wet/dry meal diet, 3) liquid meal diet, 4) dry pelleted diet, 5) wet/dry pelleted diet, and 6) liquid pelleted diet. Pigs fed all treatments were provided ad libitum access to feed.

Animal management

All treatments were applied in the same room to avoid an environmental effect. The groups of six pigs were penned in slatted pens (2.37 m × 2.36 m) with solid PVC partitions. Each pen was provided with a drinking bowl (DRIK-O-MAT, Egebjerg International A/S, Egebjerg, Denmark). The air temperature was maintained at 20 to 22 °C and was recorded daily. The room was mechanically ventilated with fans and inlets controlled by a Steinen PCS 8100 controller (Steinen BV, Nederwert, The Netherlands). Pigs were observed closely twice daily. Any pig showing signs of ill-health was treated as appropriate and all veterinary treatments were recorded including the identity of pig, symptom, the medication used, and dosage. Pigs were allowed a 14-d adaptation period in the experimental facility to adapt to the new environment and feed delivery methods. During this period all pigs were fed their diet in meal form.

Treatments 1 and 4 were fed from double spaced dry feeders (Irish Dairy Services [IDS], Portlaoise, Ireland; 104.1 cm [height, H] × 35.6 cm [depth, D] × 58.4 cm [width, W]), with one feeder per pen (six pigs per feeder). Treatments 2 and 5 were fed from single-space wet/dry feeders (IDS; 104.1 cm [H] × 36.8 cm [D] × 30.5 cm [W]) that were fitted with a water nipple in the trough so that pigs could mix the dry feed with water at their preferred water to feed ratio. There was one single-space wet/dry feeder per pen (six pigs per feeder). The liquid feed treatments were fed from short steel troughs (100 cm × 32.5 cm × 21 cm, Big Dutchman, Vechta, Germany) located on top of a rubber mat (1.5 × 1 m) to help minimize feed wastage. Each pen was equipped with a solenoid valve and a short trough fitted with an electronic sensor. The electronic sensors were checked four to six times per day and troughs with feed below the level of the sensor were refilled with their respective dietary treatments. The short-trough sensor liquid feed system ensured ad libitum access to feed.

Diet preparation and feeding

Diets were manufactured in meal and pellet form at the Teagasc feed mill. Cereals were ground through a 3 mm screen before mixing. The ingredient composition and nutrient content of the experimental diet are given in Table 1 and the same diet specification was used in all treatments. Pelleted diets were manufactured to a diameter of 3 mm after steam heating to 55 °C for ~30 s using a steam conditioner and pellet press (RE 410, Rouselle, France). The die used was 3 mm (diameter) × 60 mm (length). With all treatments, pigs were provided with ad libitum access to feed and care was taken to minimize feed wastage. Where the delivery method was dry or wet/dry, feed flow to troughs was restricted so that half of the feed pan was covered with feed. Where liquid feeding was concerned, troughs were monitored closely before, during, and after feeding and the feeding curve adapted daily for each pen, as required, to ensure ad libitum access to feed while also minimizing liquid feed wastage. This was monitored by recording the feed level in troughs before and after feeding daily and increasing or decreasing the amount of feed delivered per pen as appropriate if a similar observation was recorded over 3 consecutive days.

Table 1. Composition of the experimental diet (on an as-fed basis, g/kg unless otherwise stated)¹

	Experimental diet
Ingredient composition ²	
Wheat	400.0
Barley	382.7
Soya bean meal	183.0
Limestone flour	11.0
Soya oil	9.7
Lysine HCl	3.8
Salt	3.0
L-Threonine	1.7
Celite	2.0
Vitamin and mineral premix ³	1.0
Mono dicalcium phosphate	1.0
DL-Methionine	0.9
L-Tryptophan	0.2
Phytase ⁴	0.1
Chemical composition	
Dry matter	877.0
Crude protein	174.0
Ash	39.2
Neutral detergent fiber	163.3
Gross energy, Mcal/kg	3.82
Lysine	10.6
Methionine	4.3
Threonine	7.2
Digestible energy, Mcal/kg ²	3.30
Net energy, Mcal/kg ²	2.34
Oil ²	25.7
SID lysine ²	10.0
Total calcium ²	6.6
Total phosphorus ²	2.6

¹Values are the mean of experimental diets from experiment 1 and experiment 2.

²Calculated values.

³Vitamin and mineral premix provided per kilogram of complete diet: Cu from copper sulphate, 15 mg; Fe from ferrous sulphate monohydrate, 24 mg; Mn from manganese oxide, 31 mg; Zn from zinc oxide, 80 mg; I from potassium iodate, 0.3 mg; Se from sodium selenite, 0.2 mg; retinyl acetate, 0.7 mg; cholecalciferol, 12.7 µg; DL-alpha-tocopheryl acetate, 40 mg; vitamin K, 4 mg; vitamin B12, 15 µg; riboflavin, 2 mg; nicotinic acid, 12 mg; pantothenic acid, 10 mg; vitamin B1, 2 mg; vitamin B6, 3 mg; and celite 2,000 mg/kg.

⁴The diet contained 500 phytase units (FYT) per kilogram feed from RONOZYME HiPhos (DSM, Belfast, UK).

Treatments 3 and 6 were fed using an automatic sensor liquid feeding system (HydroMix, Big Dutchman). The diet was mixed with water (2.5:1 water:feed on a fresh matter basis) in mixing tanks with a 6 pale agitator. Diet agitation time was 10 min for batch 1 and 20 min for batch 2. Following agitation, the liquid feed was delivered using air at high pressure from the mixing tanks to troughs which were fitted with electronic feed sensors. Separate mixing tanks were used for meal and pelleted diets.

Records and feed sampling

Pigs were weighed on days 1, 14, 37, 55, and 62 during both batches of the experiment. ADG was calculated on an individual pig basis, then totaled for the pen and an average for the pen used. ADFI and gain-to-feed ratio (G:F) were calculated on a pen basis. Feed disappearance for liquid diets (treatments 3 and 6) was exported from the liquid feeding computer on a fresh matter basis and used to calculate ADFI. Feed disappearance for the dry (treatments 1 and 4) and wet/dry (treatments 2 and

5) delivery methods was calculated manually by subtracting the remaining feed at the end of each period from the total feed delivered to the trough during the period of interest. Feed intake and growth rates were monitored until day 62 of each batch. Pigs removed from the trial for health reasons were weighed and their weight gain and feed intake accounted for when calculating growth and G:F.

Feed samples from each of the six treatments were collected on days 1, 27, and 57 of each batch of the experiment for microbiological analysis. On each of the sampling days, one sample was collected from the feed storage bins for liquid feeding (one storage bin for meal, one storage bin for pellets), feed bags (from which the dry and wet/dry feeders were filled), hoppers, and mixing tank, while samples from two troughs per liquid-fed treatment were sampled approximately three hours after feed-out. All feed samples were put on ice and transported to the laboratory for analysis on the same day.

At the same time points, representative samples of each diet were also taken before feeding in each batch of the experiment for proximate and amino acid analysis. In addition, for proximate and amino acid analysis, feed samples (~250 g) were also taken from each of the storage bins used for the liquid diets, from the bagged diet used for wet/dry and dry feeding, from each of the mixing tanks used for the liquid diets, and from the liquid diet troughs (two per treatment) on day 57 of batch 1 and days 27 and 57 of batch 2. These samples were frozen at -20 °C prior to oven drying at 55 °C for 72 h prior to analysis.

Slaughter, carcass records, and blood sampling

Pigs were slaughtered at 101.0 kg ± 1.03 SE body weight (BW) by CO₂ stunning followed by exsanguination. To calculate carcass growth rates and G:F, a kill-out percentage of 65% was applied to the initial pig weight (Lawlor and Lynch, 2005). The following calculations were used: carcass ADG = [(carcass weight - initial BW × 0.65) × 1,000] and carcass G:F = carcass ADG/overall ADFI. Blood samples for hematological analysis were collected during exsanguination from 36 pigs (1 pig, which had not received veterinary treatment, selected at random from each pen, resulting in a total of 9 pigs per treatment) from each batch of the experiment (N = 72) using Vacuette tubes (Labstock, Dublin, Ireland) containing EDTA to prevent clotting. Cold carcass weight was estimated by multiplying the weight of the hot eviscerated carcass 45 min after slaughter by 0.98 according to standard procedures (Department of Agriculture, 2001). Kill-out percentage was calculated as carcass weight/BW at slaughter. BWs were collected on an individual pig basis 16 h prior to slaughter at the farm. Pigs were fasted at the time of BW collection. The back-fat thickness and muscle depth measured at 6 cm from the edge of the split back at the level of the third and fourth last rib were determined using a Hennessy Grading Probe (Hennessy and Chong, Auckland, New Zealand). Lean meat content was estimated according to the following formula: Estimated lean meat content (%) = 60.3 - 0.847x + 0.147y, where x = fat depth (mm); y = muscle depth (mm) (Department of Agriculture, 2001).

Hematological analysis of blood samples

Hematological analysis was performed on whole blood within 6 h of collection using an Abbott Cell-Dyn 3700 analyzer (GMI-Inc, Minnesota, USA). Hematological analysis was carried out as the treatments were likely to result in differences in the microbial load of feed. Therefore, hematological analysis was used as a health indicator and to investigate if there was a treatment effect on white and red blood cells. The following parameters

were measured: white blood cells (WBC), lymphocyte number and percentage, monocyte number and percentage, granulocyte number and percentage, eosinophil number and percentage, basophil number and percentage, red blood cells, hemoglobin, mean corpuscular volume, mean corpuscular hemoglobin, platelets and packed cell volume.

Microbiological analysis of feed

Approximately 10 g of each feed sample was homogenized as a 10-fold dilution in maximum recovery diluent (MRD; Oxoid, Basingstoke, UK) in a stomacher and a 10-fold dilution series was performed in MRD. Relevant dilutions were plated in duplicate as follows: 1) pour-plated on De Man Rogosa and Sharpe (Merck, Darmstadt, Germany) agar, containing 50 U/mL nystatin (Sigma-Aldrich, Arklow, Co. Wicklow, Ireland), overlaid and incubated at 30 °C for 72 h for lactic acid bacteria (LAB); 2) pour-plated on Violet Red Bile Glucose (Oxoid) agar overlaid and incubated at 37 °C for 24 h for Enterobacteriaceae; 3) pour-plated on ChromoCult Tryptone Bile X-glucuronide (Merck) agar and incubated at 44 °C for 24 h for *Escherichia coli*; and 4) spread-plated on Yeast Glucose Chloramphenicol (Merck) agar and incubated at 25 °C for 5 d for yeast and mold. Colonies were counted and the counts from duplicate plates averaged, log-transformed, and presented as $\log_{10}$ colony-forming units (cfu)/g of the original sample. Counts below the detection limit (10 cfu) were reported at the detection limit. Prior to statistical analysis, counts from dry feed samples from the storage bins and bagged diets were combined to create “dry diet” data.

Proximate and amino acid analysis of feed

Prior to analysis samples were ground in a Christy Norris mill through a 2 mm screen. Dry matter (DM, AOAC.934.01) and ash (AOAC.942.05) concentration were determined according to the method of the Association of Official Analytical Chemists (AOAC; AOAC, 2005). The Nitrogen content was determined using the LECO FP 528 instrument (Leco Instruments UK Ltd, Cheshire, UK) (AOAC.990.0). Crude protein (CP) was determined as Nitrogen $\times$ 6.25. The neutral detergent fiber (NDF) content was determined according to the method of Van Soest et al. (1991) using an Ankom 220 Fiber Analyzer (Ankom Technology, Macedon, NY). Gross energy (GE) was determined using an adiabatic bomb calorimeter (Parr Instruments, Moline, IL). Amino acid determination was carried out using cation-exchange HPLC as previously described by McDermott et al. (2016) (AOAC 994.12).

Statistical analysis

Growth parameters (ADG, ADFI, G:F, and BW), carcass quality parameters, and hematology data were analyzed using the MIXED procedure of SAS 9.4 (SAS Institute, Inc., Cary, NC). Data from batch 1 and batch 2 were analyzed together as all measurements were recorded at the same time points. For growth parameters, feed form, feed delivery, and their associated interactions were included in the model as fixed effects. Initial BW was included as a covariate when significant in the model. The day was included as a repeated measure and pen was the experimental unit. For carcass growth parameters (carcass ADG and carcass G:F), feed form and feed delivery and their interaction were included in the model as fixed effects with pen as the experimental unit. A random effect of pen within block was included in the model for all growth parameters. For carcass quality and hematology parameters, feed form and feed delivery and their interaction were included in the model as fixed effects with pen as the experimental unit. Initial BW was used as a covariate for carcass weight. All hematology data were checked

for normality as described below and log-transformed prior to analysis where data were non-normal.

Counts of LAB, Enterobacteriaceae, yeast, and mold were log-transformed as outlined above and analyzed using the MIXED procedure of SAS 9.4. Counts from samples collected on days 1, 27, and 57 of each batch were included in the analysis. Sampling location (dry feed, mixing tank, or liquid feed from the trough), feed form, and their associated interaction were included as main effects in the model, with batch as a random effect and day included as a repeated measure. *Escherichia coli* counts could not be analyzed in the same way due to normality issues with the data so the LOGISTIC procedure was used on censored data with location and feed form in the model.

The normality of scaled residuals was investigated using the Shapiro-Wilk and Kolmogorov-Smirnov tests within the UNIVARIATE procedure of SAS. Results are presented as least squares means $\pm$ SEM. Differences were considered significant at $P < 0.05$ and as tendencies at $0.05 < P < 0.10$.

Results

Pig removals

Three pigs were removed during batch 1 of the experiment: two due to lameness (one each from the wet/dry pellets and liquid pellets treatments, respectively) and one due to a rupture (from the wet/dry pellets treatment). Six pigs were removed during batch 2: three due to lameness (one pig each from the liquid pellets, liquid meal, and dry meal treatments, respectively), one due to a broken back (from the dry meal treatment), one due to a rupture (from the dry pellets treatment), and one due to rectal discharge (from the liquid meal treatment).

Effect of feed form $\times$ feed delivery on the growth and carcass quality of grow-finisher pigs

The effects of feed form by feed delivery interactions on pig growth parameters and carcass quality are reported in Table 2. During the overall period, a tendency for a feed form $\times$ delivery interaction was observed for ADG. Pigs fed a meal diet using dry or wet/dry feed delivery grew similarly but slower than those fed a liquid meal diet; however, when fed a pelleted diet, both wet/dry and liquid feeding tended to increase ADG compared with dry feeding ($P = 0.07$). The interaction for ADFI for the overall period was not significant. During the overall period, a feed form $\times$ delivery interaction was observed for G:F. Feed efficiency was improved for pigs fed a pelleted diet compared to a meal diet when feed delivery was dry or wet/dry, but not when the pelleted diet was liquid-fed ($P < 0.01$).

There was a feed form $\times$ delivery interaction for pig BW at day 62 ($P < 0.001$). When fed a meal diet, liquid-fed pigs were heavier than dry- and wet/dry-fed pigs, while pigs fed a wet/dry pelleted diet were similar in weight to those fed a liquid pelleted diet ($P < 0.001$). There was a tendency for an interaction for carcass ADG ($P = 0.09$). When fed a meal diet, wet/dry-fed pigs grew faster than dry-fed, while pigs fed a pelleted dry and wet/dry diet grew similarly. There was an interaction for carcass G:F ($P < 0.01$). Pigs fed a meal diet via dry, wet/dry, and liquid delivery had similar carcass G:F, while pigs fed a liquid pelleted diet had a worse carcass G:F than those fed dry or wet/dry. A tendency for a feed form $\times$ feed delivery interaction was observed for carcass muscle depth. Muscle depth was not affected by feed delivery when the diet was pelleted, but when the diet was in meal form, liquid-fed pigs had a higher fat depth than dry- or wet/dry-fed pigs ($P = 0.09$). There were no feed form $\times$ feed delivery

Table 2. Effect of feed form (meal or pellets) by delivery (dry, wet/dry, or liquid) interaction on the body weight, average daily gain, average daily feed intake, feed conversion efficiency, and carcass characteristics of grow-finisher pigs (N = 12 pens/treatment)¹

Form Delivery	Meal			Pellet			P-value			
	Dry	Wet/dry	Liquid	Dry	Wet/dry	Liquid	SEM	Form × delivery	Form	Delivery
BW, kg ²										
Day 1	32.9	32.8	32.4	32.7	32.4	33.2	0.48	0.10	0.80	0.67
Day 14	46.0	46.9	47.0	46.4	46.8	48.1	0.78			
Day 37	69.7 ^c	71.0 ^{a,b,c}	74.0 ^{a,b}	70.8 ^{b,c}	72.3 ^{a,b,c}	74.6 ^a	0.78	0.41	0.48	0.15
Day 55	88.3 ^c	91.0 ^{b,c}	96.6 ^a	91.0 ^{b,c}	93.3 ^{a,b}	96.2 ^a	0.78	0.001	0.11	0.001
Day 62	95.7 ^c	98.1 ^{b,c}	105.1 ^a	98.8 ^{b,c}	101.5 ^{a,b}	104.7 ^a	0.78	0.001	0.01	0.001
ADG, g/d ²										
Day 1 to 14	889 ^B	943 ^{A,B}	955 ^{A,B}	901 ^B	939 ^{A,B}	1,033 ^A	39.2	0.09	0.34	0.03
Day 15 to 37	1,027 ^d	1,047 ^{c,d}	1,172 ^a	1,065 ^{c,d}	1,105 ^{b,c}	1,151 ^{a,b}	39.2	0.03	0.41	0.01
Day 38 to 55	1,026 ^b	1,109 ^{a,b}	1,249 ^a	1,130 ^{a,b}	1,170 ^{a,b}	1,204 ^{a,b}	39.2	0.001	0.19	0.001
Day 56 to 62	1,289 ^{a,b}	1,189 ^b	1,472 ^a	1,312 ^{a,b}	1,412 ^a	1,448 ^a	39.2	0.001	0.01	0.001
Overall	1,057 ^c	1,072 ^c	1,212 ^A	1,102 ^{B,C}	1,156 ^{A,B}	1,209 ^A	22.6	0.07	0.01	0.001
ADFI, g/d ²										
Day 1 to 14	1,838 ^b	1,942 ^{a,b}	1,946 ^{a,b}	1,706 ^b	1,848 ^{a,b}	2,116 ^a	55.2	0.001	0.67	0.001
Day 15 to 37	2,325 ^b	2,394 ^b	2,719 ^a	2,177 ^b	2,349 ^b	2,786 ^a	55.2	0.001	0.35	0.001
Day 38 to 55	2,549 ^c	2,749 ^{b,c}	3,225 ^a	2,600 ^{b,c}	2,845 ^b	3,150 ^a	55.2	0.001	0.59	0.001
Day 56 to 62	2,639 ^c	2,787 ^{b,c}	3,509 ^a	2,795 ^{b,c}	2,950 ^b	3,501 ^a	55.2	0.001	0.02	0.001
Overall	2,338	2,468	2,850	2,320	2,498	2,888	38.9	0.72	0.59	0.001
G:F, g/g ²										
Day 1 to 14	0.476	0.481	0.483	0.523	0.500	0.481	0.01166	0.01	0.01	0.23
Day 15 to 37	0.436 ^{a,b}	0.433 ^{a,b}	0.424 ^{a,b}	0.484 ^b	0.465 ^b	0.406 ^a	0.0116	0.001	0.01	0.001
Day 38 to 55	0.397 ^{a,b}	0.397 ^{a,b}	0.377 ^a	0.428 ^b	0.400 ^{a,b}	0.378 ^a	0.0116	0.01	0.15	0.01
Day 56 to 62	0.477 ^d	0.421 ^{a,b,c}	0.409 ^{a,b}	0.461 ^{b,c,d}	0.471 ^{c,d}	0.406 ^a	0.0116	0.001	0.21	0.001
Overall	0.446 ^{b,c}	0.433 ^{a,b}	0.423 ^a	0.474 ^d	0.459 ^{c,d}	0.418 ^a	0.0080	0.01	0.001	0.001
Carcass										
ADG, g/d ³	823 ^F	868 ^D	954 ^{A,B}	880 ^{C,D}	918 ^{B,C}	967 ^A	12.1	0.09	0.001	0.001
G:F, g/g ⁴	0.355 ^a	0.354 ^a	0.342 ^a	0.387 ^b	0.375 ^b	0.342 ^a	0.0050	0.01	0.001	0.001
Cold-weight, kg	73.0	75.8	81.0	76.4	78.8	82.0	0.75	0.11	0.001	0.001
Kill-out, %	76.1	77.0	77.0	77.2	77.5	78.0	0.30	0.39	0.001	0.01
Muscle, mm	50.2	51.4	51.8	50.8	51.9	52.2	0.51	0.94	0.18	0.005
Fat, mm	11.4 ^c	12.0 ^{B,C}	13.8 ^A	11.9 ^{B,C}	12.4 ^{B,C}	13.1 ^{A,B}	0.35	0.09	0.79	0.001
Lean meat, %	58.0	57.7	56.3	57.7	57.5	56.9	0.29	0.12	0.90	0.001

¹Least squares means and pooled standard errors of the mean are presented. Values are the mean of data from both batches of the experiment.
²BW, body weight; ADFI, average daily feed intake; ADG, average daily gain; G:F, gain-to-feed ratio.
³Carcass ADG = From weight at start of experiment to slaughter = (carcass weight in kg – BW on day 1 × 0.65) / number of days on treatment (Lawlor and Lynch, 2005).
⁴Carcass Gain:Feed = From start of experiment to slaughter = carcass ADG (g)/total average daily feed intake.
^{a,b,c,d}Within each row, values that do not share a common superscript are significantly different (P < 0.05).
^{A,B,C,D,E}Within each row, values that do not share a common superscript tend to be different (0.05 < P < 0.10).

interactions for the other carcass quality parameters measured in the current study.

Effect of feed form on the growth and carcass quality traits of grow-finisher pigs

During the overall period, ADG was 1,114 and 1,156 g/d (SE = 16.9; $P < 0.01$) and G:F was 0.434 and 0.450 g/g (SE = 0.0066; $P < 0.001$) for meal- and pellet-fed pigs, respectively. Providing the diet in meal or pelleted form did not influence ADFI during the overall period. Pig BW at day 62 was 99.7 and 101.7 kg (SE = 0.51; $P < 0.001$) for meal- and pellet-fed pigs, respectively. At slaughter, carcass weight was 76.6 and 79.0 kg (SE = 0.55; $P < 0.001$) and kill-out yield was 76.7% and 77.6% (SE = 0.22; $P < 0.001$).

Effect of feed delivery method on the growth and carcass quality traits of grow-finisher pigs

During the overall period, ADG was 1,080, 1,114, and 1,210 g/d (SE = 18.4; $P < 0.001$), ADFI was 2,329, 2,483, and 2,869 g/d (SE = 55.2; $P < 0.001$), and G:F was 0.460, 0.446, and 0.420 (SE = 0.0070; $P < 0.001$) for dry-, wet/dry-, and liquid-fed pigs, respectively. Pig BW at day 62 was 97.3, 99.8, and 104.9 kg (SE = 0.59; $P < 0.001$) for pigs fed using dry, wet/dry, and liquid delivery systems, respectively. At slaughter, carcass weight was 74.7, 77.3, and 81.5 kg (SE = 0.60; $P < 0.001$), kill-out percentage was 76.7%, 77.3%, and 77.5% ($P < 0.01$), muscle depth was 50.5, 51.6, and 52.0 mm (SE = 0.40; $P < 0.01$), fat depth was 11.7, 12.2, and 13.4 mm (SE = 0.28; $P < 0.001$), and lean meat percentage was 57.9%, 57.6%, and 56.6% (SE = 0.23; $P < 0.001$) for dry-, wet/dry-, and liquid-fed pigs.

Microbiological quality of dry diets fed via dry and wet/dry feeders and liquid feed prepared for grow-finisher pigs

Microbial counts in the dry diets and liquid feed samples collected from the mixing tanks and feed troughs are given in Table 3. Significant feed form $\times$ sampling location interactions were observed for LAB, Enterobacteriaceae, and yeast counts. Lower LAB, Enterobacteriaceae, and yeast counts were seen when the diet was dry in pelleted form compared to in meal form; however, no differences were observed in the mixing tank or troughs between feed forms.

In terms of feed form, LAB counts were 6.17 and 5.84 $\log_{10}$ cfu/g (SE = 0.126; $P = 0.07$), Enterobacteriaceae counts were 5.47 and 4.86 $\log_{10}$ cfu/g (SE = 0.193; $P < 0.01$), yeast counts were 4.25 and 4.03 $\log_{10}$ cfu/g (SE = 0.135; $P = 0.07$), and mold counts were 4.11 and 3.78 $\log_{10}$ cfu/g (SE = 0.158; $P < 0.05$) for meal and pellets, respectively (data not shown).

For sampling location, LAB counts were 2.79, 6.84, and 8.38 $\log_{10}$ cfu/g (SE = 0.155; $P < 0.001$), Enterobacteriaceae counts were 4.25, 5.12, and 6.13 $\log_{10}$ cfu/g (SE = 0.217; $P < 0.001$), yeast counts were 3.52, 3.63, and 5.27 $\log_{10}$ cfu/g (SE = 0.147; $P < 0.001$), and mold counts were 3.38, 4.09, and 4.37 $\log_{10}$ cfu/g (SE = 0.173; $P < 0.001$) for dry feed, mixing tank, and liquid feed trough samples, respectively (data not shown). Results for *E. coli* counts showed that it was 143 times more likely to find *E. coli* in the liquid feed troughs than in the mixing tanks or dry feed.

Effect of feed form and delivery on GE, CP, ash, NDF, and amino acid content of the feed

The means and standard deviations of GE, CP, ash, NDF, and amino acid content of the meal and pelleted feed at the sampling locations described above are given in Table 4. There was no obvious decrease in GE or CP content of the feed when levels in the dry diet, mixing tank, and trough are compared. There is evidence of some loss of NDF and lysine in liquid-fed troughs compared to the dry diet.

Effect of feed form and delivery methods on the hematological profile of pigs at slaughter

The hematological profile of pigs at slaughter is given in Table 5. No significant feed form $\times$ feed delivery interactions were found. A tendency for feed form $\times$ feed delivery was observed for packed cell volume; however, there were no pairwise differences between treatments ($P > 0.05$). Feed delivery did not affect any of the parameters measured. Hemoglobin levels in pigs fed the diet in meal and pellet form were 14.25 and 13.74 g/dL (SE = 0.169; $P < 0.05$), mean corpuscular hemoglobin was 17.27 and 16.60 pg (SE = 0.194; $P < 0.05$), WBC counts were 2.07×10^{10} and 2.30×10^{10} cells/L (SE = 6.93×10^8 ; $P < 0.05$), and neutrophil counts were 1.28×10^9 and 1.48×10^9 cells/L (SE = 6.07×10^8 ; $P < 0.05$), respectively. However, hemoglobin levels were within the normal range for pigs (10 to 16 g/dL), but mean corpuscular hemoglobin levels

Table 3. Microbial counts ($\log_{10}$ cfu/g) in dry diets and in the dietary treatments collected from the mixing tanks and from the feed troughs in the pig pens^{1,2}

Form Delivery	Meal			Pellet			SEM	P-value		
	Dry ³	Mixing tank ⁴	Trough ⁵	Dry ³	Mixing tank ⁴	Trough ⁵		Sampling location $\times$ feed form	Sampling location	Feed form
LAB	3.30 ^b	6.77 ^c	8.45 ^d	2.29 ^a	6.92 ^c	8.31 ^d	0.219	0.03	0.001	0.07
Enterobacteriaceae	5.24 ^{b,c}	5.09 ^b	6.09 ^{b,c}	3.26 ^a	5.15 ^{b,c}	6.18 ^c	0.276	0.001	0.001	0.01
Yeast	3.92 ^b	3.64 ^{a,b}	5.20 ^c	3.12 ^a	3.63 ^{a,b}	5.35 ^c	0.178	0.01	0.001	0.07
Mold	3.75	4.17	4.42	3.00	4.01	4.32	0.213	0.14	0.001	0.03

¹*Escherichia coli* counts were omitted from this analysis due to normality issues with the data. Therefore, a logistic procedure was used to calculate the likelihood of presence or absence of *E. coli* in the mixing tank or dry feed compared to in the trough and these data are presented in the text.

²Values are the mean of data from samples taken on days 1, 27, and 57 of batch 1 and on the same days during batch 2, i.e., from 6 time points.

³Dry: represents dry feed samples collected from the storage bins used for preparing liquid feed and bagged diets used for feeding dry and wet/dry feed.

⁴Mixing tank: represents samples of liquid feed collected at the end of the agitation process.

⁵Trough: represents samples taken from liquid-fed troughs only, collected approximately three hours after feed-out.

^{a,b,c,d}Within each row, values that do not share a common superscript are significantly different ($P < 0.05$).

Table 4. Proximate analysis of dry diets and liquid feed collected from the mixing tanks and troughs for both the meal and pelleted diets¹ (presented on a dry matter basis)

Form Delivery	Meal			Pellets			SD
	Dry ³	Mixing tank ³	Trough ⁴	Dry ²	Mixing tank ³	Trough ⁴	
Gross energy, Mcal/kg	4.37	4.45	4.30	4.35	4.52	4.35	0.080
Crude protein, %	19.9	20.4	21.0	19.7	22.0	20.7	1.36
Ash, %	4.3	3.7	5.2	4.6	3.8	5.0	0.64
NDF, %	18.7	16.3	14.7	18.5	18.7	15.0	2.79
Amino acids, g/kg							
Lysine	12.1	9.7	10.0	12.1	11.3	9.3	1.29
Cysteic acid	5.4	5.3	5.9	5.3	5.6	5.5	0.27
Taurine	0.5	2.5	1.3	0.9	1.9	1.2	0.71
Methionine	5.0	5.2	4.7	4.8	5.0	4.6	0.28
Aspartic acid	17.1	17.4	18.3	17.1	18.3	16.4	1.49
Threonine	8.0	8.4	8.2	8.3	8.8	7.8	0.46
Serine	9.3	9.4	10.1	9.3	10.0	9.3	0.69
Glutamic acid	43.5	43.5	47.2	42.8	45.7	44.8	2.85
Glycine	8.1	8.5	9.0	8.1	9.0	8.3	0.57
Alanine	7.8	8.1	8.7	7.7	8.9	8.0	0.68
Cysteine	0.5	1.4	0.8	0.6	1.2	1.0	0.43
Valine	9.4	9.5	10.2	9.4	10.5	9.3	0.68
Isoleucine	7.6	7.9	8.4	7.6	8.3	7.5	0.68
Leucine	13.7	14.2	15.1	13.7	15.0	13.7	1.11
Tyrosine	5.2	4.4	5.6	5.2	5.3	5.2	0.60
Phenylalanine	9.6	9.7	10.4	9.5	10.3	9.5	0.72
Histidine	5.7	6.0	5.8	5.7	6.0	5.8	0.40
Arginine	11.8	11.9	11.7	11.8	12.3	10.9	0.88
Proline	12.9	13.8	14.9	13.0	14.7	13.8	1.05

¹Means and their associated standard deviation are presented for each sampling location.

²Dry: represents dry feed samples collected from the storage bins used for preparing liquid feed and bagged diets used for feeding dry and wet/dry feed; mean of four samples presented.

³Mixing tank: represents samples of liquid feed collected at the end of the agitation process; mean of two samples presented.

⁴Trough: represents samples taken from liquid-fed troughs only, collected approximately three hours after feed-out; mean of two samples presented.

were slightly below the normal range of 17 to 21 pg for pigs on wet/dry meal, dry pellets, and wet/dry pellets, WBC counts were above the normal range for grow-finisher pigs (11 to 22×10^9 cells/L) on each of the pelleted diets, and neutrophil counts were above the normal range of 3.08 to 10.45×10^9 cells/L for all treatments. The normal ranges referred to are those specified for pigs by [Jackson and Cockcroft \(2008\)](#).

Discussion

Optimum feed form and delivery for grow-finisher pigs

To our knowledge, this study is the first to compare feed form (meal and pellet) and feed delivery method (dry, wet/dry, and liquid) under the same environmental conditions. Such a study is fundamental to determine the optimum combination of feed form and delivery methods to optimize pig growth, feed efficiency, and ultimately profitability in commercial pig production. The results here can be utilized by commercial pig producers to inform investment decisions when it comes to planning new, or upgrading existing, facilities. Our results suggest that to optimize feed efficiency, dry or wet/dry feeding of a pelleted diet would be the preferred feeding strategy. Furthermore, the method of feed delivery chosen will determine whether feed should be pelleted or not. Our results suggest an advantage of pelleting when the diet is fed via dry or wet/dry hoppers, but that there is no growth or feed efficiency advantage of liquid feeding a pelleted diet over

a meal diet. The results of the current study suggest that feeding a pelleted diet from a dry or a wet/dry feeder will optimize G:F in grow-finisher pigs compared with all other feed form and delivery methods assessed. However, according to [Patience et al. \(2015\)](#), the advantage of pelleting in improving feed efficiency is confounded by particle size, as a greater benefit from pelleting is found the larger the particle size of the meal that is pelleted. Although not measured in the current study, producers should be mindful that a further reduction in particle size associated with the pelleting of an already finely ground meal can increase the risk of stomach ulceration ([De Jong et al., 2016](#)). Furthermore, and although this was not the case in the current study, others have found that pelleting can increase carcass fatness in pigs ([Nemechek et al., 2015b](#)).

The current study shows a G:F advantage with dry or wet/dry feeding of a pelleted diet compared with dry or wet/dry feeding of the same diet in meal form. These results are in contrast to those of [Myers et al. \(2013\)](#) who reported similar G:F for wet/dry feeding of a meal and pelleted diet but showed a poorer G:F in pigs fed a pelleted diet from a dry feeder compared with a meal diet from the same type of feeder. They explained that a high proportion of fines in their pelleted diet most likely explained the poorer G:F found with pellets, indicating the importance of pellet quality ([Myers et al., 2013](#)). In contrast somewhat to the findings of the current study, wet/dry meal feeding and dry feeding a pelleted diet have also been shown to improve feed efficiency compared to dry meal feeding in grow-finisher pigs ([Chae, 2000](#)). A 6.3% improvement in G:F was reported here by

Table 5. Effect of feed form (meal or pellets) by delivery (dry, wet/dry, or liquid) interaction on the hematological profile of pigs at slaughter (N = 18/treatment)¹

Form	Meal			Pellet			SEM	P-value		
	Dry	Wet/dry	Liquid	Dry	Wet/dry	Liquid		Form × Delivery	Form	Delivery
White blood cells, ×10 ⁹ cells/L	20.8	20.7	20.5	22.7	22.5	23.7	1.20	0.80	0.02	0.91
Lymphocytes										
%	25.3	30.7	27.6	26.4	25.4	26.9	1.99	0.26	0.33	0.54
×10 ⁹ cells/L	5.1	6.3	5.5	6.0	5.6	6.1	3.69	0.10	0.40	0.56
Monocytes										
%	8.7	8.9	9.6	9.0	8.6	7.5	0.84	0.34	0.31	0.92
×10 ⁹ cells/L	1.8	1.8	2.0	2.0	2.0	1.8	2.09	0.57	0.86	0.99
Granulocytes										
Neutrophils										
%	64.4	58.8	61.0	62.7	64.0	64.2	1.97	0.20	0.17	0.55
×10 ⁹ cells/L	13.6	12.3	12.6	14.3	14.5	15.5	1.52	0.58	0.03	0.79
Eosinophils										
%	0.2	0.1	0.1	0.2	0.2	0.1	0.05	0.42	0.54	0.12
×10 ⁹ cells/L	0.03	0.03	0.03	0.05	0.04	0.02	0.099	0.37	0.39	0.29
Basophils										
%	1.4	1.5	1.7	1.7	1.8	1.3	0.24	0.25	0.75	0.82
×10 ⁹ cells/L	0.29	0.33	0.35	0.38	0.40	0.33	0.053	0.53	0.30	0.90
Red blood cells, ×10 ¹² cells/L	8.4	8.3	8.1	8.2	8.4	8.3	0.17	0.43	0.79	0.75
Hemoglobin, g/dL	14.6	14.0	14.1	13.4	13.7	14.1	0.29	0.10	0.03	0.69
Mean corpuscular volume, fL	58.8	57.5	57.2	56.6	55.6	57.9	1.32	0.49	0.29	0.64
Mean corpuscular hemoglobin										
Concentration, g/dL	29.6	29.5	30.9	29.0	29.7	29.4	0.63	0.39	0.20	0.40
Pg	17.4	16.9	17.5	16.4	16.4	17.0	0.34	0.72	0.02	0.28
Platelets, × 10 ⁹ cells /L	201.5	220.2	252.5	284.2	241.0	260.1	269.70	0.34	0.10	0.64
Packed cell volume, L/L	0.49	0.47	0.46	0.46	0.46	0.48	0.010	0.06	0.34	0.60

¹Least squares means and pooled standard errors of the mean are presented. Values are the mean of data from both batches of the experiment.

feeding a dry pelleted diet compared with a dry meal diet which agrees with the 7% improvement in feed efficiency reported by Wondra et al. (1995b). Carcass ADG in the current study increased for wet/dry compared to dry feeding of meal but not when the diet was pelleted which supports the suggestion of Gonyou and Lou (2000) that increases in ADG for wet/dry feeding compared to dry feeding a diet would be greater for a meal diet than a pelleted diet, due to the higher eating speed with pelleted diets.

The advantages of pelleting in terms of optimizing G:F found when feeding dry or wet/dry diets were not found with liquid feeding. In agreement, l'Anson et al. (2013) found no improvement in G:F due to pelleting when liquid feeding was practiced, despite finding an improvement with dry feeding. It is likely that liquid feeding reduced dust losses normally associated with feeding meal, thereby negating the response to pelleting. Furthermore, the reduction in feed wastage normally associated with feeding a dry pelleted diet may have been nullified due to the increased ADFI associated with liquid feeding.

Impact of feed delivery method on pig growth and feed efficiency

In the current experiment, the treatments with the highest feed intakes (wet/dry and liquid) had water available at the point of feeding. One reason for increased feed intake in wet/dry over dry feeding suggested by Averós et al. (2012) is that both hunger and thirst motivate pigs to visit the feeder, compared with hunger alone with dry feeding. Additionally, eating speed is increased when diets are mixed with water (Gonyou and Lou, 2000; Bergstrom et al., 2012), which may also help to explain the increased ADFI found with wet/dry and liquid feeding compared

with dry feeding in the current experiment. Others also found ADFI to increase in response to wet/dry feeding compared with dry feeding (Brumm et al., 2000; Gonyou and Lou, 2000; Bergstrom et al., 2008; Bergstrom et al., 2012; Myers et al., 2013).

ADG was increased by liquid feeding compared with dry- and wet/dry feeding in the current study. Others have also found this to be the case when liquid feeding was compared with dry feeding (Braude and Rowell, 1967; Russell et al., 1996; Kim et al., 2001; Stotfold Research Centre, 2005; Hurst et al., 2008; l'Anson et al., 2012). A higher eating rate has been found with liquid feeding which helps to explain the associated increase in growth rate (Braude, 1967; Hurst et al., 2008). In studies where no differences in ADG between liquid- and dry feeding were found (Dung et al., 2005; Zoric et al., 2015), it is likely that the feeding curves or daily feed allowances were restrictive, particularly in the study by Dung et al. (2005), and as such prevented pigs from reaching their true intake and growth potential.

The poorer G:F observed in the current study in liquid-fed pigs is most likely due to increased feed wastage. Troughs were located at ground level and despite the use of solid rubber mats under and around them to minimize feed wastage it was possible for pigs to remove feed with their feet and faces at feeding time. Feed wastage was easier to control in the dry and wet/dry feeders due to good control of the release rate of the feed from hopper to trough. Increased feed wastage with liquid feed resulting in poor feed efficiency has also been reported in other studies (Russell et al., 1996; Han et al., 2006; Plumed-Ferrer and Von Wright, 2009; Missotten et al., 2010; l'Anson et al., 2012). Liquid feeding as practiced in the current study allowed ad libitum access of pigs to the liquid feed. A 7% to 10% improvement in G:F is possible if

access to liquid feed is restricted (Hurst et al., 2008). Therefore, one could speculate that if a restricted liquid feeding regime was used in the current study, the G:F of liquid-fed pigs could be improved to levels observed for dry and wet/dry feeding.

Influence of feed form on the growth and feed efficiency of grow-finisher pigs

Pelleting the diet in the current experiment resulted in an increased ADG but not ADFI. It is likely that this is due to reduced feed wastage (Patterson, 1989) and improved nutrient digestibility (Seerley et al., 1962; Wondra et al., 1995a; O'Doherty et al., 2001; Ball et al., 2015) in response to pelleting. Pelleting diets has long been associated with improved feed utilization efficiency and nutrient digestibility (Hanrahan, 1984). In agreement with previous reports (Seerley et al., 1962; Stark et al., 1993; Wondra et al., 1995a; Mikkelsen et al., 2004; Hedemann et al., 2005; l'Anson et al., 2012; Millet et al., 2012; l'Anson et al., 2013; Myers et al., 2013; Ball et al., 2015; Nemecek et al., 2015a; De Jong et al., 2016), the G:F of dry and wet/dry pellet-fed pigs was significantly improved in the current study.

The impact of feed pelleting and delivery method on the microbiological quality and proximate analysis of feed

There is evidence that spontaneous fermentation occurred in the liquid feed in the current study, as counts of LAB and yeast increased significantly from dry feed to the mixing tank and again to the trough in both meal and pelleted form. Despite the fact that there were significantly lower LAB and yeast counts in the dry pelleted diet than in the dry meal diet, LAB and yeast counts in liquid feed troughs were similar between meal and pellets. This suggests that LAB and yeast growth is not affected by feed form once the feed is mixed with water. It also seems that pelleted feed is of better microbiological quality, as evidenced by the lower Enterobacteriaceae counts observed in dry pelleted feed compared to dry meal feed. This is in agreement with previous work by our group, where lower Enterobacteriaceae counts were also found in pelleted vs. meal feed in a survey of feed from commercial feed mills, likely due to the high temperatures used in the pelleting process (Burns et al., 2015). This may in part explain the improved growth rate in pigs fed the pelleted diet in dry or wet/dry form compared to meal-fed pigs using the same delivery system, as lower Enterobacteriaceae counts may indicate a lower prevalence of *Salmonella*, for example, in the feed (Veldman et al., 1995; Jones and Richardson, 2004). Furthermore, a systematic review has concluded that there is a low level of comfort that pelleting feed increases *Salmonella* prevalence in finisher pigs (O'Connor et al., 2008). It was, however, somewhat surprising that Enterobacteriaceae counts were similar between dry meal and liquid feed prepared from the meal when the latter was sampled from the feed trough. These high Enterobacteriaceae counts are indicative of poorer feed microbial quality and could be another reason that the G:F of pigs fed dry and wet/dry pelleted diets was increased compared to those fed dry and wet/dry meal diets.

Although based on a small number of samples, lysine concentrations in liquid feed from the mixing tank and troughs were lower than those in the corresponding dry meal and pelleted feed samples. Amino acid degradation is a drawback that has long been associated with fermented liquid feeding (Pedersen, 2001; Brooks, 2008), but evidence of its existence in fresh liquid feed is lacking. However, in the present study, it did not seem to impact the growth of pigs but it is likely to have contributed to the poorer G:F observed for liquid feeding.

The impact of feed form and delivery on the hematological profile of pigs

An interesting observation was that pelleting the diet resulted in lower hemoglobin and mean corpuscular volume and higher WBC and neutrophil counts in the blood compared to meal-fed pigs in the current study. However, hemoglobin levels were within the normal range, but mean corpuscular hemoglobin levels were slightly below the normal range for pigs on dry and wet/dry pellets, total WBC counts were above the normal range on all of the pelleted diets and neutrophil counts were above the normal range for all treatments (normal ranges for pigs as specified by Jackson and Cockcroft (2008)). Pelleting reduces the particle size of the diet and is also associated with gastric ulceration (Vukmirović et al., 2017; Krauss et al., 2018). One could speculate that lower hemoglobin levels in pellet-fed pigs may be early indicators of subclinical ulceration associated with a reduced particle size of the diet. Ulceration may also explain the elevated WBC count in these animals. In fact, previous work has shown higher WBC counts in piglets fed finely ground compared to coarsely ground corn (Huang et al., 2015).

In conclusion, the current study suggests that to achieve the best carcass G:F in grow-finisher pigs, dry or wet/dry feeding of a pelleted diet is optimal. Liquid feeding a meal or pelleted diet maximized carcass daily gain; however, as pelleting the diet did not increase carcass growth rate compared with meal in liquid-fed pigs, liquid feeding a meal will in practice be used to maximize growth rate. Wet/dry feeding a pelleted diet achieved a similar growth rate to liquid feeding a meal diet and because it also optimizes G:F, subject to economic assessment, it is the recommended method of feeding grow-finisher pigs based on this study. Investigations to determine if restricted liquid feeding in comparison to ad libitum liquid feeding can improve G:F are warranted to optimize feed efficiency where liquid feeding is practiced.

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Conflict of interest statement

The authors declare no conflict of interest.

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