Effects of preslaughter feed withdrawal time on finishing pig carcass, body weight gain, and food safety characteristics in a commercial environment[1,2,3]

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ABSTRACT: The effects of feed withdrawal time before slaughter on finishing pig carcass composition were evaluated in 2 studies. In Exp. 1, 728 pigs (BW = 128.9 ± 1.2 kg) were allotted to 1 of 4 treatments in a randomized design with number of pigs per pen and location within barn balanced across treatment. The 4 treatments were feed withdrawal times of 8, 24, 36, or 48 h and there were 12 replicate pens per treatment. Before feed withdrawal, pigs were fed a standard corn–soybean meal diet containing dried distillers grains with solubles (DDGS), bakery coproducts, and 5.0 mg/kg ractopamine HCl. Feed withdrawal time decreased (linear; $P < 0.02$) live weight, HCW, and backfat while increasing percentage yield (quadratic; $P < 0.01$) and fat-free lean index (FFLI; linear; $P < 0.001$). In Exp. 2, 843 pigs (BW = 125.4 ± 1.6 kg) were used to determine the impact of feed withdrawal on growth, carcass, blood lactate, and meat quality. There were 4 treatments: withholding feed for 8, 12, 24, or 36 h, with 10 replicates per treatment. Pigs were fed a common corn–soybean meal–based diet containing 20% DDGS and 5.0 mg/kg ractopamine HCl. Withholding feed decreased (linear; $P < 0.001$) live weight, ultimately resulting in decreased ($P < 0.01$) HCW. There were no differences in FFLI or backfat, but percentage yield (linear; $P < 0.001$) increased with longer withdrawal times. Carcass contaminations by stomach contents escaping from the oral cavity after shackling (leaking ingesta) or visible fecal contamination of the exterior of the carcass (runny bung) were also measured. Although withholding feed did not affect runny bung, it increased (linear; $P < 0.001$) the incidence of leaking ingesta, whereas blood lactate, visual color score, and purge loss were unaffected. Withholding feed increased 45-min pH (quadratic; $P > 0.02$) and ultimate pH (linear; $P < 0.01$) and increased (quadratic; $P < 0.03$) visual marbling score. Withholding feed decreased (linear; $P < 0.001$) feed intake, resulting in feed savings of up to 3 kg/pig. Although several heavyweight pigs were removed before trial commencement and the variable number of remaining pigs per pen may have influenced the response to feed withdrawal, the present data indicates that finishing pigs can experience between 24 and 36 h of feed withdrawal without negatively affecting carcass composition. However, the increased incidence of leaking ingesta beyond 12 h of feed withdrawal is concerning.

Key words: carcass, fasting, feed withdrawal, swine

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INTRODUCTION

Finishing pigs inherently experience a period of feed deprivation during transport and lairage. Feed withdrawal before transportation for slaughter reduces feed intake and thereby increases feed savings (Kephart and Mills, 2005); furthermore, pigs with a full stomach are more difficult to handle (Eikelenboom et al., 1991) and are more likely to experience transport sickness (Bradshaw et al., 1996). Fasting also reduces gut fill, which decreases the likelihood of carcass contamination by inadvertently

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lacerating the gastrointestinal tract during evisceration (Eikelenboom et al., 1991; Miller et al., 1997) and ultimately reduces waste at the abattoir (Eikelenboom et al., 1991). Withholding feed before slaughter also has been shown to affect pork quality by reducing muscle glycogen levels at the time of exsanguination, leading to a higher ultimate pH (Warriss and Brown, 1983), lower drip loss (Eikelenboom et al., 1991), and consequently lower incidence of pale, soft, and exudative pork (Murray and Jones, 1994).

Extended periods (>24 h) of feed restriction, however, can increase pig aggression (Kelley et al., 1980) and skin and carcass damage (Brown et al., 1999). Extending feed restriction beyond 18 h may also reduce carcass weight (Saffle and Cole, 1960; Warriss and Brown, 1983) and increase the incidence of dark, firm, and dry pork (Guardia et al., 2009). Due to the potentially deleterious effects of long feed withdrawal on pork quality, recommended times before slaughter currently range from 8 to 24 h (Eikelenboom et al., 1991; Warriss, 1994); however, little work has evaluated the economic implications of increasing feed withdrawal before slaughter. Therefore, the primary objectives of this study were to examine the effects of varying feed withdrawal length on finishing pig BW gain and carcass and food safety characteristics.

MATERIALS AND METHODS

General

All practices and procedures used in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee number 3120. Both trials were conducted at commercial research finishing facilities in southwestern Minnesota. These facilities were double-curtain-sided with completely slatted flooring and deep pits for manure storage. The research barn contained 48 pens (3.05 by 5.49 m) equipped with a 5-hole conventional dry feeder (STACO, Inc., Schaefferstown, PA) and a cup waterer, which afforded ad libitum access to feed and water. In both experiments, an automated feeding system (FeedPro; Feedlogic Corp., Willmar, MN) was used to deliver and record feeding amounts on an individual pen basis. All complete diets, ground corn, and supplements were manufactured at the New Horizons Feed Mill (Pipestone, MN) and were formulated to meet or exceed all requirement estimates (NRC, 1998). Feed intake was also recorded during the 48-h period before slaughter.

In both experiments, pigs were transported (approximately 95 km) for slaughter to a commercial abattoir (JBS Swift and Company, Worthington, MN). The transit time was approximately 2 h, and this time period was included in the respective treatment durations in both experiments. Pigs were individually tattooed according to pen number to allow for data retrieval by pen and carcass data collection at the abattoir. The abattoir had an average line speed of 1,090 animals per hour. All animals were rendered irreversibly unconscious using 90% CO_2 exposure in a dip-lift system for a minimum of 3 min per animal. Hot carcass weights were measured immediately after evisceration, and each carcass was evaluated for percentage yield, backfat, and loin depth. Percentage yield was calculated by dividing HCW by live weight obtained at the farm before transport to the abattoir. Fat depth and loin depth were measured with an optical probe (Fat-O-Meater; SFK Technology, Herlev, Denmark) inserted between the third and fourth ribs located anterior to the last rib at a distance approximately 7.1 cm from the dorsal midline. Fat-free lean index (**FFLI**) was calculated using National Pork Producers Council (2000) guidelines for carcasses measured with the Fat-O-Meater such that FFLI = {15.31 + [0.51 × (0.4536 × HCW,kg)] - [31.277 × (0.0394 × last-rib fat thickness, cm)] + [3.813 × (0.0394 × loin muscle depth, cm)]/(0.4536 × HCW, kg)}.

Experiment 1

A total of 728 female and surgically castrated male pigs (337 × 1050; PIC, Hendersonville, TN; initially 128.9 ± 1.2 kg BW) were used with 10 to 19 pigs per pen and 12 replicate pens per treatment in a randomized design. Pens were ranked by mean pig BW and then treatments were allotted to each of 48 pens, with pigs per pen and location within the barn balanced across treatment. Pens were mixed gender and had ad libitum access to water throughout the experiment.

Experimental treatments were designed to reflect the amount of time that pigs had feed removed before exsanguination. The 4 treatments were 1) feed access up until point of loading on the day of slaughter (8 h), 2) 24-h feed withdrawal, 3) 36-h feed withdrawal, and 4) 48-h feed withdrawal. A standard commercial diet (Table 1) containing 5 mg/kg ractopamine HCl (**RAC**; Paylean, Elanco Animal Health, Greenfield, IN) was fed throughout the experiment. The diet was corn–soybean meal based and contained dried distillers grains with solubles (**DDGS**) and bakery coproducts (Table 1). Before allotment, the heaviest pigs and underweight or cull pigs were removed from each pen according to the farm's normal marketing procedure. Pigs were initially weighed by pen at 52 h before exsanguination to allow time for allotment before the application of the 48-h treatment (Table 2). At this time, feed amounts in each feeder were recorded. The FeedPro system recorded any additional feed delivered to each pen during the experiment. When treatments were applied, feeders were shut off and cleaned and the remaining feed recorded for calculation of feed intake during the test period. Pigs were also weighed by pen immediately before loading for transport to the abattoir.

The 3 trucks were loaded so that a balanced number of pens per treatment were included on each truck. Duration from the beginning of loadout, which started at 0900 h, until the first pig was exsanguinated was approximately 8 h. This included approximately 4 h for loadout and transit and approximately 4 h of lairage. Upon arrival at the slaughter plant, pigs were again weighed by pen. During lairage, pigs had ad libitum access to water but not feed.

Experiment 2

A total of 843 female and surgically castrated pigs (1050; PIC, Hendersonville, TN; initially 125.4 ± 1.6 kg BW) were used with 16 to 26 pigs per pen and 10 replicate pens per treatment in a randomized complete block design (**RCBD**). Pens were ranked by mean pig BW within pen, and pens were allotted to 1 of 4 experimental treatments with pigs per pen and previous dietary treatment balanced across treatments. Experimental treatments were 1) feed access until the point of loading on the day of slaughter (8 h), 2) 12-h feed withdrawal, 3) 24-h feed withdrawal, and 4) 36-h feed withdrawal. Pigs were initially weighed by pen 42 h before exsanguination to allow time for allotment before the application of the 36-h treatment (Table 3). At this time, feed amounts in each feeder were recorded. The FeedPro system recorded any additional feed delivered to each pen during the experiment. Treatments were applied and pigs were weighed and loaded as in Exp. 1.

Before allotment, the heaviest pigs and underweight or cull pigs (determined visually) were removed from each pen according to the farm's normal marketing procedure. A common corn–soybean meal–based diet that contained 20% DDGS diet with 5 mg/kg RAC was fed throughout the experiment. Ad libitum access to feed and water was provided.

To eliminate any transportation effects, pigs were loaded onto 4 commercial swine transport trailers so that a balanced number of pens per treatment were included on each truck. Loadout began at 0300 h and concluded at approximately 0500 h, with all trucks arriving at the plant before 0800 h. Actual time when the first pig was exsanguinated was 1205 h. Mean time between loadout and slaughter was 8 h across treatments. Upon arrival at the abattoir, pigs were again weighed by pen. During lairage, pigs had access to water but not feed.

Although 843 pigs and 10 replicate pens per treatment were initially allotted to this experiment, data were recovered from only 25 pens (543 pigs; initially 125.2 ± 1.5 kg BW) as a result of pig misidentification at the abattoir. Of 25 pens, carcass data was collected from 7, 7, 6, and 5 pens for the 8-, 12-, 24-, and 36-h treatments, respectively.

Table 1. Composition of diets, Exp. 1 and 2 (as-fed basis)

Item	Experiment 1	Experiment 2
Ingredient, %		
Corn	29.86	61.45
Soybean meal, 46.5% CP	13.05	16.56
Bakery byproduct	29.88	–
Dried distillers grains with solubles	25.00	20.00
Limestone	1.20	1.03
Salt	0.09	0.35
Vitamin and trace mineral premix[1]	0.08	0.09
Lys sulfate, 50.7%	0.70	0.45
L-Thr	0.12	0.02
Phytase[2]	0.012	–
Ractopamine HCl[3]	0.050	0.050
Total	100	100
Calculated analysis		
SID[4] amino acids, %		
Lys	0.96	0.90
Ile:Lys	64	69
Met:Lys	31	32
Met and Cys:Lys	58	65
Thr:Lys	70	65
Trp:Lys	16	18
Val:Lys	77	83
Total Lys, %	1.10	1.04
ME, kcal/kg	3,457	3,364
SID Lys:ME, g/Mcal	2.76	2.67
CP, %	19.25	18.71
Ca, %	0.56	0.47
P, %	0.43	0.43
Available P, %[5]	0.28	0.21

[1]Provided per kilogram of premix: 4,509,409 IU vitamin A, 701,463 IU vitamin D_3, 24,050 IU vitamin E, 1,403 mg vitamin K, 3,006 mg riboflavin, 12,025 mg pantothenic acid, 18,038 mg niacin, and 15.0 mg vitamin B_{12}. Also provided per kilogram of premix: 40.1 g Mn from manganese oxide and manganese sulfate, 90.2 g Fe from iron sulfate, 100.2 g Zn from zinc oxide, 10.0 g Cu from copper sulfate, 501 mg I from ethylenediamine dihydroiodide, and 301 mg Se from sodium selenite.

[2]Optiphos 2000 (Enzyvia LLC, Sheridan, IN).

[3]Paylean (Elanco Animal Health, Greenfield, IN), fed at 5 mg/kg in the final diet.

[4]SID = standardized ileal digestible.

[5]Phytase provided 0.09% available P in Exp. 2.

Intestinal Evaluation

Runny bung and leaking ingesta were evaluated in Exp. 2 due to concerns about a relationship with feed withdrawal. Runny bung was defined as visible contamination of the exterior of the carcass from feces, and leaking ingesta was defined as stomach contents escaping from the oral cavity after being suspended by the calcaneal tendon after exsanguination. Both measurements were determined visually at the inspection station by trained plant personnel on a per-pig basis (yes or no), collected, and recorded as overall percentage prevalence per pen.

Table 2. Effects of preslaughter feed withdrawal on finishing pig performance and carcass traits in a commercial environment, Exp. 1[1]

	Feed withdrawal, h[2]					Probability, $P <$	
Item	8	24	36	48	SED	Linear	Quadratic
Pig BW, kg							
48 h before marketing	129.9	129.6	130.1	129.8	1.75	0.93	0.90
At loading on farm[3]	131.0	128.6	125.4	124.4	1.59	0.001	0.17
Upon arrival at abattoir[3]	128.8	125.5	122.8	121.9	1.57	0.001	0.10
Feed intake/pig marketed, kg	6.25	3.68	1.88	1.22	0.276	0.001	0.001
Weight change, kg	1.1	–1.0	–4.7	–5.4	0.33	0.001	0.001
HCW, kg	95.8	95.5	93.8	93.1	1.26	0.02	0.67
Yield, %[4]	74.43	76.09	76.35	76.40	0.327	0.001	0.001
Fat depth, mm[5]	17.0	16.5	16.2	16.0	0.32	0.01	0.26
Loin depth, mm[5]	63.2	63.8	63.7	64.2	0.81	0.35	0.97
FFLI, %[5,6]	52.81	53.14	53.41	53.58	0.221	0.001	0.31

[1]A total of 728 pigs (initially 129.9 ± 1.24 kg BW) were used with 12 replicate pens per treatment and an average of 15 pigs per pen.

[2]Actual time feed was withheld before slaughter. The 8-h treatment served as control.

[3]Duration from the beginning of loadout, which started at 0900 h, until the first pig was exsanguinated was approximately 8 h. This included approximately 4 h for loadout and transit and approximately 4 h of lairage.

[4]Yield % = HCW/(wt at arrival to abattoir × 100).

[5]Adjusted with HCW as a covariate.

[6]Fat-free lean index (FFLI) was calculated using National Pork Producers Council (2000) guidelines for carcasses measured with the Fat-O-Meater (SFK Technology, Herlev, Denmark) such that FFLI = {15.31 + [0.51 x (0.4536 x HCW,kg)] - [31.277 x (0.0394 x last-rib fat thickness, cm)] + [3.813 x (0.0394 x loin muscle depth, cm)]/(0.4536 x HCW, kg)}.

Lactate and Meat Quality Analyses

In Exp. 2, a subsample of 2 barrows per pen (n = 96) were selected to represent the approximate median BW per pen and were individually identified with a unique tattoo and ear tag to indicate collection of blood lactate (**LAC**) measurements and meat quality characteristics (Table 4). These animals were sampled for LAC levels at 2 different time points during the marketing process: 1) postloading and 2) exsanguination.

During loading, pigs were moved between 15 and 77 m down a 0.9-m-wide alleyway, depending on pen location, by farm personnel and researchers. The portable loading ramp used was 0.95 m wide and the ramp was at a 16° incline. Electric prods were used when necessary while pigs were entering and moving up the loading chute. These pigs were loaded into 2 separate compartments on the first truck to collect LAC and prevent mixing with the remainder of the trial pigs. After the subsample of 96 barrows was loaded onto the first truck and before loading the remaining compartments, researchers entered the trailer to collect the postloading blood sample for LAC analysis. Sorting boards were used to segregate pigs for blood collection, but no physical restraint methods were used. Blood lactate collection was conducted according to Edwards et al. (2010). The animal's distal ear vein was pricked using a retractable 20-gauge needle. Afterward, a sample strip was inserted into a precalibrated handheld lactate analyzer (Lactate Scout; EKF Diagnostic GmbH, Magdeburg, Germany), and a drop of blood from the animal's ear was immediately administered to the sample strip. The analyzer provided LAC in approximately 15 s and results were recorded. Upon arrival at the abattoir, the trucker and plant personnel unloaded all animals, and the 96 barrows for meat quality analysis were housed in a single lairage pen independently from other pigs.

The second blood sample was collected within 10 s of exsanguination; blood was collected in potassium oxalate sodium fluoride tubes, which were then sealed and placed on ice until all 96 barrows were slaughtered. Immediately after collection, samples were analyzed with the handheld lactate analyzer used for the postloading LAC sample. Before data collection at both time points, handheld lactate analyzers were tested using a standard solution to ensure accuracy (CV = 6.0%).

For meat quality analyses, the left side of the carcass was used throughout the trial. All pH measurements were recorded using a pH meter (model 9025; Hanna Instruments, Smithfield, RI) with a glass-tipped probe. The pH measurements were taken at 3 time points to evaluate the pH decline postslaughter: 45 min, 3 h, and 21 h. At each time point, the probe was inserted into the longissimus thoracis (**LT**) between the 10th and 11th rib. Approximately 24 h postmortem, carcasses were fabricated for sample collection and additional analysis. A 40-cm section of the LT was removed from the posterior end of the loin, individually labeled, and allowed to bloom for 30 min. After blooming, subjective color and marbling score were determined by a trained evaluator using the 1 to 6 scoring system for color and

Table 3. Effects of preslaughter feed withdrawal time on finishing pig performance and carcass traits in a commercial environment, Exp. 2[1]

Item	Feed withdrawal, h[2]				SED	Probability, $P <$	
	8	12	24	36		Linear	Quadratic
Pig BW, kg							
48 h before marketing	123.3	124.3	125.8	125.6	2.01	0.25	0.48
At loading on farm[3]	125.6	125.4	123.5	121.5	0.26	0.001	0.24
Upon arrival at abattoir[3]	122.8	122.5	120.4	118.8	0.46	0.001	0.94
Feed intake/pig marketed, kg	3.54	3.14	1.78	0.58	0.174	0.001	0.72
Weight change, kg[4]	0.1	–0.1	–2.0	–4.0	0.26	0.001	0.27
HCW, kg[4]	92.6	92.5	91.6	91.4	0.47	0.01	0.48
Yield, %[5]	75.15	75.30	76.05	77.02	0.435	0.001	0.64
Fat depth, mm[6]	20.3	19.9	20.5	19.6	0.586	0.47	0.43
Loin depth, mm[6]	56.3	56.8	56.2	57.7	1.73	0.53	0.60
FFLI, %[6,7]	50.41	50.74	50.33	50.90	0.395	0.42	0.45
Runny bung, %[8]	4.02	2.38	6.59	4.80	3.30	0.50	0.57
Leaking ingesta, %[8]	3.17	4.34	9.39	19.60	4.165	0.001	0.39

[1]Of 40 pens (843 pigs) initially allotted to this experiment, only 25 pens (543 pigs; 125.2 ± 1.5 kg initial BW) were used as a result of data lost at the plant. Number of observations: 7 pens at 8 h, 7 pens at 12 h, 6 pens at 24 h, and 5 pens at 36 h.

[2]Actual time feed was withheld before slaughter. The 8-h treatment served as control.

[3]Duration from the beginning of loadout, which started at 0900 h, until the first pig was exsanguinated was approximately 8 h. This included approximately 4 h for loadout and transit and approximately 4 h of lairage.

[4]Adjusted with d 0 pig BW as a covariate.

[5]Yield % = HCW/(wt at arrival to abattoir × 100).

[6]Adjusted with actual HCW as a covariate.

[7]Fat-free lean index (FFLI) was calculated using National Pork Producers Council (2000) guidelines for carcasses measured with the Fat-O-Meater (SFK Technology, Herlev, Denmark) such that FFLI = {15.31 + [0.51 × (0.4536 × HCW,kg)] - [31.277 × (0.0394 × last-rib fat thickness, cm)] + [3.813 × (0.0394 × loin muscle depth, cm)]/(0.4536 × HCW, kg)}

[8]Prevalence per pen.

1 to 10 scoring system for marbling (NPPC, 2000). The LT was subsequently vacuum packaged and transported on ice to the Kansas State University Meat Laboratory (Manhattan, KS) for subsequent analysis. Samples were stored at 4°C and aged for 10 d postslaughter. At that time, ultimate pH was recorded by placing the probe into the LT at a central position across the sirloin face. Purge loss at 10 d postslaughter was measured by initially weighing the packaged LT and then removing the packaging and pat-drying both the packaging and the LT sample. After the dried package and LT sample were weighed, purge loss was calculated as a percentage of the original LT weight. After pH and color analyses, LT samples were repackaged and frozen at –80°C.

Statistical Analysis

In both experiments, pen was used as the experimental unit for growth, carcass, and economic analyses. In Exp. 1, data were analyzed as a randomized design using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Experiment 2 was a RCBD with previous treatment as the blocking factor. The statistical model included the fixed effect of withdrawal treatment with block as the random component. In Exp. 2, the misidentification of several pens at the abattoir and the subsequent removal of their preslaughter data resulted in variation in initial pig BW taken at 36 h before slaughter. As a consequence, initial pig BW was used as a covariate for growth and HCW. In both experiments, HCW was used as a covariate for fat depth, loin depth, and FFLI. For the subsample of barrows in Exp. 2, treatments were also arranged in an RCBD, as in the overall experiment. The PROC MIXED procedure was used to analyze meat quality parameters, and both block and pen were evaluated as random effects. For both experiments, means were evaluated using linear and quadratic CONTRAST statements in SAS. The coefficients for the unequally spaced linear and quadratic contrasts were derived using PROC IML in SAS. Least square means were calculated for each independent variable. Results were considered to be significant if P-values were ≤0.05 and considered tendencies if P-values were ≤0.10.

RESULTS

Experiment 1

The results in Exp. 1 are outlined in Table 2. Pigs that experienced increased periods of preslaughter feed withdrawal had decreased live weight at loadout (linear; $P < 0.001$) and at the abattoir (linear; $P < 0.001$),

Table 4. Effects of preslaughter feed withdrawal time on blood lactate and meat quality measurements in finishing pigs, Exp. 2[1]

	Feed withdrawal, h[2]					Probability, $P <$	
Item	8	12	24	36	SED	Linear	Quadratic
Blood lactate, mM[3]							
Postloading[3]	4.85	4.11	4.72	5.09	0.795	0.45	0.58
Exsanguination	6.44	7.50	6.87	7.83	0.675	0.14	0.76
Longissimus thoracis pH							
45 min	6.57	6.65	6.71	6.59	0.060	0.78	0.02
3 h	6.50	6.52	6.56	6.50	0.054	0.85	0.18
21 h	5.85	5.90	5.89	5.93	0.039	0.08	0.87
Ultimate	5.84	5.92	5.89	5.99	0.051	0.01	0.68
Visual color score[4]	3.63	3.71	3.80	3.56	0.239	0.80	0.30
Visual marbling score[4]	1.77	1.99	2.26	1.90	0.216	0.51	0.03
10-d purge loss, %	1.53	1.58	1.51	1.29	0.195	0.16	0.48

[1]Two median weight barrows per pen (n = 80) were selected for lactate and meat quality analyses. Data shown are from 79 carcasses.

[2]Actual time feed was withheld before slaughter. The 8-h treatment served as control.

[3]Collected using a handheld lactate analyzer (Lactate Scout; EKF Diagnostic GmbH, Magdeburg, Germany).

[4]National Pork Producers Council standards (NPPC, 2000).

resulting in a greater amount of weight change from 48 h preslaughter up to unloading and weighing at the abattoir (quadratic; $P < 0.001$); this effect was most drastic beyond 24 h of feed withdrawal. Withholding feed decreased (quadratic; $P < 0.001$) feed intake per pig marketed, resulting in increased (quadratic; $P < 0.001$) feed savings of over 5 kg per pig from 8 to 48 h. For carcass characteristics, pigs that fasted for increasing lengths of time had lighter (linear; $P < 0.02$) HCW than control pigs subjected to normal transit and lairage times (8 h) from this location. Increased withdrawal time also increased (quadratic; $P < 0.001$) percentage yield. Extending feed withdrawal times increased FFLI (linear; $P < 0.001$) and decreased (linear; $P < 0.01$) backfat depth but had no effect ($P > 0.35$) on loin depth.

Experiment 2

The results from Exp. 2 are outlined in Table 2. Although 843 pigs and 10 replicate pens per treatment were initially allotted to this experiment, data were recovered from only 25 pens (543 pigs, initially 125.2 +/- 1.5 kg BW) as a result of pig misidentification at the packing plant. Of the original 10 replicates per treatment, complete data were collected on 7 pens from the 8-h control group, 7 pens from the 12-h treatment, 6 pens from the 24-h group, and 5 pens from the 36-h treatment; therefore, the on-farm live BW and feed intake data also reflect only the 25 pens from which carcass data were obtained.

No differences ($P > 0.25$) were detected in d-0 BW across treatments for the remaining pens at allotment. As expected, feed intake per pig marketed decreased (linear; $P < 0.001$) as feed withdrawal time increased, resulting in feed savings of up to 3 kg/pig. As in Exp. 1, increased duration of feed withdrawal decreased (linear; $P < 0.001$) live weights at loadout and on arrival at the abattoir, and overall live BW change was thereby reduced (linear; $P < 0.001$) by increased feed withdrawal time. Furthermore, the reduction in live BW by increased feed withdrawal ultimately resulted in decreased (linear; $P < 0.01$) HCW and increased (linear; $P < 0.001$) percentage yield. In addition, unlike in Exp. 1, no differences ($P > 0.42$) were observed in FFLI or backfat depth. As in Exp. 1, there were also no differences ($P > 0.53$) in loin depth.

The prevalence of runny bung within each pen was similar ($P > 0.50$) across all treatments, but the prevalence of leaking ingesta within each pen greatly increased (linear; $P < 0.001$) with longer periods of feed withdrawal. This was most evident in the 36-h treatment, where 19.6% of pigs within each pen exhibited leaking ingesta. This rate is concerning because visible leaking ingesta is a major criterion for head condemnation and results in a loss of approximately 2.5% of the carcass value.

For meat quality analyses, LAC measurements were similar ($P > 0.45$) across treatments after loading as well as at exsanguination. Longer feed withdrawal periods increased (quadratic; $P < 0.02$) 45-min pH, but there were no differences at 3 h postmortem ($P > 0.18$) in LT pH. Even so, at 21 h postmortem, longer feed withdrawal periods tended to increase (linear; $P < 0.08$) LT pH, agreeing with ultimately higher pH values (linear; $P < 0.01$) in pigs subjected to extended feed withdrawal. Although feed withdrawal time did not significantly affect ($P > 0.30$) visual pork color, pigs that experienced longer feed withdrawal periods had higher (quadratic; $P < 0.03$) visual marbling scores, which appeared to peak at the 36-h time point. Purge loss did not differ ($P > 0.16$) between withdrawal treatments.

DISCUSSION

Preslaughter feed withdrawal reduces live BW, primarily due to the emptying of the gastrointestinal tract. Results from Warriss and Brown (1983), Kephart and Mills (2005), and Panella-Riera et al. (2012) suggest that at a point between 12 and 18 h of feed restriction before slaughter there is a reduction in HCW. Warriss and Brown (1983) estimated that fasting pigs for between 18 and 48 h resulted in carcass weight loss of 0.11% per hour. In the current study, the rate of loss in HCW between 24 and 48 h preslaughter was 0.11% per hour in Exp. 1, but in Exp. 2 the loss rate was lower, at 0.05% per hour between 12 and 36 h of feed withdrawal. Reasons for the differences between the present experiments are unclear, but associated effects may include differences in ambient temperature and the time of day during feed interactions as well as the large number of misidentified carcasses during Exp. 2.

Feed withdrawal time also increased carcass yield by 2.0% at 48 h in Exp. 1 and by 1.8% at 36 h in Exp. 2. In previous studies, this increase has been linked to a decrease in overall viscera weight (Kephart and Mills, 2005), particularly gut fill (Jones et al., 1985) and liver weight, which Warriss and Brown (1983) described as occurring rapidly over the first 24 h and then stabilizing at about 80% of initial, unfasted weight. The decrease in liver weight is primarily attributed to a loss of water and glycogen. Decreases in muscle glycogen and water content are also linked to the reduction in HCW that begins to occur within 12 to 18 h of feed withdrawal (Jones et al., 1985).

In Exp. 1, extended feed withdrawal time increased calculated FFLI through a decrease in backfat, but this response did not occur in Exp. 2. Although previous research has shown variable effects on backfat depth (Beattie et al., 2002; Leheska et al., 2002), there is little evidence that fasting for short periods before slaughter affects overall backfat or FFLI.

From the standpoint of food safety, an important finding of the present study was the increased prevalence of leaking ingesta with longer periods of feed withdrawal. This was most evident in the 36-h treatment, where 19.6% of pigs in each pen exhibited leaking ingesta compared with only 3.2% in the control group. Leaking ingesta is a major criterion for head contamination, which can result in losses of approximately 2.5% of overall carcass value. This matches data from Panella-Riera et al. (2012) suggesting that pigs may increase water intake during fasting, thereby altering stomach contents to a more fluid state that can escape up the esophagus when shackled. Based on the results of the present study, the occurrence of leaking ingesta appears to begin increasing between 12 and 24 h, but the greatest increases occur beyond 24 h of feed restriction. Morrow et al. (2002) reported that feed withdrawal did not affect the percentage of pigs with *Salmonella* organisms in their cecal contents, although they were present in 62% of pigs at slaughter. Despite concerns about contaminating the exterior of the carcass with cecal contents, feed withdrawal had no effect on the prevalence of runny bung, which was only observed in 4.3% of pigs per pen across treatment.

In Exp. 2, LAC measurements were taken to evaluate stress levels of fasted pigs after loading and again at exsanguination. Edwards et al. (2010) showed that LAC at exsanguination can be used to monitor the adequacy of animal handling systems before slaughter as well as to monitor the rate of early postmortem metabolism and muscle drip loss. In the present study, increasing feed withdrawal time did not affect LAC after loading or after exsanguination. These results agree with results of Fernandez et al. (1995) and Bertol et al. (2005), who both reported no effect of feed withdrawal on LAC concentration in rested or stressed pigs. Similarly, Hambrecht et al. (2005) saw no difference in exsanguination LAC concentration when pigs were subjected to a 2 × 2 factorial with short or long time periods during both transport and lairage.

The increase in 45-min and ultimate LT pH with increasing feed withdrawal time seen in the current study not only agrees with prior research by Panella-Riera et al. (2012) but also shows that ultimate pH continues to increase in the LT from 12 to 36 h of feed withdrawal, coinciding with responses seen in the semimembranosus and the adductor in Warriss and Brown (1983). This consistent increase in ultimate pH has been correlated with darker color scores in previous research (Leheska et. al., 2002), but in the present study no differences were observed in visual color score. This result agrees with Kephart and Mills (2005), who saw no differences in color between 6 and 24 h of feed withdrawal. These results are also supported by Faucitano et al. (2006) and Panella-Riera et al. (2012), neither of whom saw differences in muscle lightness (L*) values when feed withdrawal was applied before slaughter. In the current study, visual marbling levels increased up to 24 h of feed withdrawal. Earlier feed withdrawal research attributed an increase in marbling to greater color contrast between fat and lean caused by the darker-colored lean in fasted pigs (Wulf et al., 2002); however, color scores in this study were not significant, and the reason for increased marbling scores remains unclear. Moreover, purge loss in this study was not influenced by feed withdrawal, although a linear decrease in drip loss typically has been associated with feed restriction (Jones et al., 1985).

While a relatively large number of heavyweight pigs were marketed before trial commencement and the variable number of pigs remaining per pen may have influenced results, the results of the present study indicate preslaughter feed withdrawal times should not exceed 24 h to minimize HCW loss. It is also important to consider feeding patterns (Hyun et al., 1997) because intake is typically lowest during night hours, so loading pigs early in the morning may elicit some of the benefits of <12 h of feed withdrawal.

Furthermore, feed withdrawal reduces gastrointestinal lacerations and waste and improves pork quality. When feed withdrawal times exceed 12 h, leaking ingesta prevalence increases; however, additional research is needed to determine the true impact on head condemnations and carcass value.

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