Kansas Agricultural Experiment Station Research Reports

Volume 9
Issue 7 *Swine Day*

Article 39

2023

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Abigail K. Jenkins
Kansas State University, Manhattan, akjenkin@k-state.edu

Jordan T. Gebhardt
Kansas State University, Manhattan, jgebhardt@k-state.edu

Jason C. Woodworth
Kansas State University, Manhattan, jwoodworth@k-state.edu

See next page for additional authors

Recommended Citation

Jenkins, Abigail K.; Gebhardt, Jordan T.; Woodworth, Jason C.; DeRouchey, Joel M.; Tokach, Mike D.; and Goodband, Robert D. (2023) "Evaluation of Variation in Nursery Pig Growth Performance Utilizing Different Allotment Strategies," *Kansas Agricultural Experiment Station Research Reports*: Vol. 9: Iss. 7. https://doi.org/10.4148/2378-5977.8540

Evaluation of Variation in Nursery Pig Growth Performance Utilizing Different Allotment Strategies

Abigail K. Jenkins, Jordan T. Gebhardt,[1] Jason C. Woodworth, Joel M. DeRouchey, Mike D. Tokach, and Robert D. Goodband

Summary

A total of 360 pigs (200 × 400 DNA) were used in a 43-d nursery trial (initially 12.4 ± 0.37 lb) to evaluate multiple strategies for allotting pigs to pens in swine research trials. At placement, the population was split into 3 cohorts with similar average weight and standard deviation. Each cohort was randomly assigned to 1 of 3 allotment strategies. Strategy 1 (random) utilized a simple randomization strategy with each pig randomized to pen independent of all other pigs. Strategy 2 [body weight (BW) distribution] sorted each pig within the cohort into 1 of 5 BW groups. One pig from each weight group was then randomly assigned to pen such that distribution of BW within pen was uniform across pens. Strategy 3 (BW grouping) sorted pigs within the cohort into 3 BW categories: light, medium, and heavy. Within each BW category, pigs were randomly assigned to pen to create pens of pigs from each BW category. There were 72 pens in the trial with 5 pigs per pen and 24 pens per allotment strategy. For all strategies, once pigs were allotted to pens, pens were allotted to 1 of 2 treatments for a concurrent trial. Treatment diets consisted of basal levels of Zn and Cu from the trace mineral premix for the duration of the study (110 and 17 mg/kg, respectively; NC), or diets (PC) with carbadox (50 g/ton; Mecadox, Phibro Animal Health, Teaneck, NJ) fed in phase 1 and 2, pharmacological levels of Zn and Cu (2,414 mg/kg Zn from ZnO; 168 mg/kg Cu from $CuSO_4$) in phase 1 and only Cu (168 mg/kg Cu from $CuSO_4$) in phase 2. There were no allotment × treatment interactions ($P > 0.10$). Pigs fed the PC diet had improved ($P < 0.001$) ADG, ADFI, F/G, and final BW compared to pigs fed the NC diet. The coefficients of variation (CV) within pen between all pens on each allotment strategy and for the entire population of each allotment strategy were calculated. For between-pen and within-pen CV, pigs allotted using the BW grouping strategy had the lowest CV at allotment and final weigh day. Results were used to estimate the replication required with each allotment strategy to obtain significant differences with different percentage responses. Fewer replications are required to discern significant differences in ADG and final BW when allotting pigs utilizing BW grouping. However, there is no meaningful difference between allotment strategies in the replications required to detect significant differences for overall feed efficiency. When conducting nursery research with pen serving as the experimental unit, the data of this trial would

[1] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

support that a BW grouping allotment strategy would produce the least within-pen and pen-to-pen variation.

Introduction

Minimizing variation is one of the foremost goals when allotting animals to pens and experimental units to treatments in swine research. Several factors have been shown to increase BW variability, including weaning weight and the many stressors that accompany the weaning process.[2] While research has been conducted in the past to decipher what effect allotment strategy has on within and between-pen variation, the results differed.[3,4] Therefore, the objective of this study was to further investigate how various allotment strategies may affect growth performance and coefficient of variation for within and between pen BW in a 43-d nursery trial.

Procedures

General

The protocol for this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. The study was conducted at the Kansas State University Segregated Early Weaning Research Facility in Manhattan, KS. The facility has two identical barns with a total of 80 pens. Each pen contained a 4-hole, dry, self-feeder and a cup waterer to provide *ad libitum* access to feed and water. Pens (4 × 4 ft) had metal tri-bar floors and allowed approximately 3.2 ft^2/pig.

Animal treatment and structure

A total of 360 barrows (200 × 400, DNA; initially 12.4 ± 0.37 lb BW) were used in a 43-d trial across two barns. There was a total of 72 pens in the trial with 5 pigs per pen. There were 24 pens per allotment strategy and 36 pens per dietary treatment. Pigs were weaned at approximately 21 days of age. Upon loading into the facility (d 0) pigs were individually weighed and the Microsoft Excel software program was used to sort the pigs in each barn from lightest to heaviest. After pigs were sorted by BW, cohorts of 3 were created and randomized to one of three allotment strategies. This cohort step was performed to ensure that the underlying populations used in each allotment strategy were as similar as possible.

The first strategy (random) utilized a completely randomized design to allot pigs to pens. Strategy 2 (body weight distribution) required pigs to be sorted by body weight and then assigned to 1 of 5 body weight groups. Then, pigs were randomly assigned to pen such that each pen contained 1 pig from each body weight group which created a relatively consistent distribution of body weights across pens. In strategy 3 (body weight grouping), the Microsoft Excel software program was used to sort pigs by body weight and assigned to one of three body weight groups: light, medium, or heavy. Then, within

[2] Tolosa A. F., J. M. DeRouchey, M. D. Tokach, R. D. Goodband, J. C. Woodworth, J. T. Gebhardt, M. J. Ritter, and C. M. Pilcher. 2021. A meta-analysis to understand the relationship between pig body weight and variation from birth to market. Animals 11(7): 2088. doi:10.3390/ani11072088.

[3] Shelton, N. W., S. S. Dritz, M. D. Tokach, R. D. Goodband, J. L. Nelsen, J. M. DeRouchey, and L. W. Murray. 2011. Effects of experimental design and its role in interpretation of results. 2009. Kansas Experimental Station Research Reports: Issue 10.

[4] Bromm, J. B., M. D. Tokach, J. C. Woodworth, R. D. Goodband, J. M. DeRouchey, and J. T. Gebhardt. 2022. Characterizing variation in nursery pig growth performance based on different allotment strategies. Kansas Experimental Station Research Reports: Volume 8, Issue 10.

each body weight group pigs were randomized to pen to create pens of pigs of a single body weight group (pens of light pigs, pens of medium pigs, and pens of heavy pigs).

After pigs were allotted to pens, pens were then allotted to 1 of 2 dietary treatments. Phase 1 diets were fed from d 0 to 22. Phase 2 treatments were fed from d 22 to 43. The phase 1 positive control diet was formulated to contain pharmacological levels of zinc (2,414 ppm from ZnO) and copper (168 mg/kg from $CuSO_4$) with carbadox (50 g/ton; Mecadox, Phibro Animal Health, Teaneck, NJ). The phase 2 positive control diet contained pharmacological levels of copper (168 ppm mg/kg from $CuSO_4$) and carbadox (50 g/ton; Mecadox, Phibro Animal Health, Teaneck, NJ). Both phases of the negative control diets were formulated to meet NRC[5] requirements for zinc (110 mg/kg) and copper (17 mg/kg) with no addition of antibiotic. Diets were manufactured at Hubbard Feeds in Beloit, KS. The phase 1 diets were fed in pelleted form and phase 2 diets were fed in meal form.

Pigs were individually weighed and feeders weighed on d 0, 8, 15, 22, 29, 36, and 43 to ascertain ADG, coefficient of body weight variation (CV), ADFI, and F/G. Records of injections administered were kept and analyzed for dietary treatment differences.

Statistical analysis

Growth performance data were analyzed using the lme4 package of R (Version 4.0.0, R Foundation for Statistical Computing, Vienna, Austria) with pen considered as the experimental unit. To test the effect of strategy on growth performance outcomes, allotment strategy was included in the model as a fixed effect. Growth performance data were also analyzed to test the effect of dietary treatment. The GLIMMIX procedure of SAS (version 9.4; Cary, NC) was used to analyze the effect of dietary treatment on number of injections per 1,000 days. Differences were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$. Using the SEM from the dietary treatment analysis, the standard deviation was calculated and used to calculate the sample size required to detect differences between the two treatments using the equation described by Dohoo et al.[6] using an α of 0.05 and β of 0.20. Values reported within the BW grouping strategy are values for total pens within each treatment group.

Results and Discussion

There were no diet × allotment strategy interactions ($P > 0.10$) observed. Additionally, within the BW grouping strategy, there were no BW group × dietary treatment interactions ($P > 0.10$) within that allotment strategy. Pigs that were fed the positive control diet were heavier at each weighing event after allotment ($P < 0.05$) and exhibited greater ADG and ADFI throughout the duration of the study ($P < 0.001$; Table 3). Feed efficiency was improved in the pigs fed the PC diet during phase 1 and overall ($P < 0.001$); however, there was only a tendency for improvement in feed efficiency during phase 2 of the study ($P = 0.078$). Pigs fed the PC diet also required 7 less total injections per 1000 pig days ($P = 0.020$; Table 3).

Body weight and ADFI were not statistically different between the three different allotment strategies throughout the entire study ($P > 0.10$; Table 2). Phase 1 feed efficiency

[5] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

[6] Dohoo, I.R., W. Martin, and H. Stryhn. 2009. Veterinary Epidemiologic Research. AVC Inc.

was improved in those pigs allotted with the body weight grouping strategy compared to those pigs allotted using the random strategy ($P < 0.05$), with those allotted using the body weight distribution strategy intermediate. There was a tendency for improved overall F/G in pigs allotted using the body weight grouping strategy compared to the other allotment strategies ($P = 0.060$). Additionally, there was a tendency for improved ADG from d 22 to 43 in pigs of the BW grouping strategy compared to those allotted using the random allotment strategy with the body weight distribution intermediate.

To elucidate the effects of each allotment strategy on variance, models were generated from the ANOVA tables for overall ADG and overall F/G. The variance term used to test for treatment effects was pen (treatment), or pen nested within treatment, in both models. Note that the difference in degrees of freedom (DF) for the error term based on strategy can affect the power to detect differences. The F-test statistic, which represents the likelihood of finding differences between treatments if they exist is high for both parameters that were analyzed in all allotment strategies. Given the clear treatment differences produced based on dietary treatment, any of the three allotment strategies would have a high level of statistical power to detect this difference.

When looking at the CV for pig BW within each pen, the BW grouping allotment strategy had the lowest CV at allotment at approximately 6% (Table 4). The within pen CV for those pens allotted using the BW grouping strategy increased throughout the first 4 weeks of the trial, but the CV still remained lower than those of the other 2 allotment strategies for the entirety of the trial. The within pen CV of those pens allotted using the random and BW distribution strategy remained fairly similar throughout the trial. The within pen CV of the BW distribution strategy was the highest at allotment and for the first four weeks of the trial but at the conclusion of the trial the CV was slightly lower than that of the random strategy.

For the CV of the mean BW between pens, at allotment, pigs allotted with the random strategy had the highest CV with pigs allotted using the BW grouping strategy having the lowest between pen CV, and those allotted using the BW distribution strategy intermediate (Table 4). The between pen CV increased at a relatively similar rate for all 3 allotment strategies until d 29 of the study, after which the CV for all 3 strategies decreased until the end of the trial. By the end of the study, the between pen CV for the random strategy was the highest, while the CV for the BW distribution was intermediate and the CV for the BW grouping strategy was slightly smaller.

Finally, when analyzing the population CV of pigs within each strategy, the initial CV calculations for pig BW were within 0.3% of each other, regardless of allotment strategy (Table 4). During the first 2 weeks of the trial, the CV for pigs allotted using the BW distribution strategy increased the most. The BW CV for BW distribution and random strategies peaked on d 29 and then fell until the conclusion of the trial. The BW CV for the BW grouping strategy peaked on d 22 and then decreased at every weighing event thereafter for the lowest population CV of the 3 allotment strategies at the conclusion of the study.

When discerning how allotment strategy affected the replications required to find statistical differences in growth performance, the pigs allotted using the BW distribution or BW grouping allotment strategies required the fewest replications per group for a 2 to 10% improvement in d 22 BW (Table 5). For final BW, the BW grouping strategy requires the least number of replications per group for a 2 to 10% improvement. Pigs allotted using the BW grouping strategy also required the fewest replications per group for a 2 to 10% improvement in ADG and F/G from d 0 to 22, ADG and ADFI from d 22 to 43, and overall ADG and ADFI (Table 5). Pigs allotted utilizing the random strategy require the least number of replications per group for a 2 to 10% improvement in overall F/G. However, as the percentage of improvement increases, the number of replications per group needed to see that improvement became more similar across the different strategies. Pigs allotted using the BW distribution strategy required the fewest number of replications per group for a 2 to 10% improvement in ADFI from d 0 to 22 and F/G from d 22 to 43 (Table 5).

In conclusion, pigs allotted using the BW grouping strategy exhibited improved ADG and F/G during the trial, driven by differences in growth performance of lightweight pigs. Overall, fewer replications would be required to find similar percentage responses when allotting pigs using the BW grouping strategy for the largest number of growth performance measurements as compared to the other allotment strategies. When conducting nursery research with pen serving as the experimental unit, the data herein would support that a BW grouping strategy would result in the least within pen and pen-to-pen variation.

Table 1. Diet composition (as-fed basis)

	Dietary phase[1]	
Item	**1**	**2**
Ingredient, %		
Corn	47.15	60.60
Soybean meal, 46.5% CP[2]	20.30	28.15
Spray-dried whey	17.50	---
Corn DDGS	5.00	7.50
Fermented soybean meal[3]	5.00	---
Choice white grease	1.50	---
Monocalcium P, 21.5% P	1.08	0.95
Calcium carbonate	0.61	0.81
Sodium chloride	0.35	0.55
Vitamin premix with phytase	0.25	0.25
Trace mineral premix	0.15	0.15
L-Lys-HCl	0.48	0.52
DL-Met	0.23	0.17
L-Thr	0.18	0.21
L-Trp	0.04	0.05
L-Val	0.10	0.11
Choline chloride, 60%	0.04	---
Vitamin E, 20,000 IU	0.05	---
Zinc oxide[4]	+/-	---
Copper sulfate[5]	+/-	+/-
Antimicrobial[6]	+/-	+/-
Total	100	100

[1] Diets were fed in a 2-phase feeding program. Phase 1 experimental diets were fed from d 0 to 22 and phase 2 experimental diets were fed from d 22 to 43.
[2] CP = crude protein.
[3] MEPRO (Prairie AquaTech, Brookings, SD).
[4] Zinc oxide was added at 0 or 6.4 lb/ton during dietary phase 1.
[5] Copper sulfate was added at 0 or 1.2 lb/ton during dietary phases 1 and 2.
[6] Mecadox 2.5 (carbadox; Phibro Animal Health, Teaneck, NJ) was added at 0 or 20.0 lb/ton during dietary phases 1 and 2.

Table 2. Evaluation of different allotment strategies on growth performance of nursery pigs[1]

Item	Random[2]	Body weight distribution[3]	Body weight grouping[4]	SEM	*P* =
BW, lb					
d 0	12.4	12.4	12.4	0.372	1.000
d 8	13.8	13.8	13.8	0.342	0.993
d 15	18.3	18.1	18.3	0.356	0.854
d 22	23.7	23.8	24.0	0.426	0.910
d 29	31.5	31.8	32.2	0.495	0.666
d 36	40.8	41.6	42.0	0.555	0.318
d 43	52.2	52.8	53.6	0.654	0.293
d 0 to 22 (Phase 1)					
ADG, lb	0.50	0.50	0.52	0.027	0.593
ADFI, lb	0.65	0.63	0.64	0.019	0.578
F/G	1.33[a]	1.27[ab]	1.26[b]	0.042	0.014
d 22 to 43 (Phase 2)					
ADG, lb	1.35[b]	1.38[ab]	1.41[a]	0.017	0.055
ADFI, lb	2.04	2.06	2.10	0.026	0.218
F/G	1.51	1.49	1.49	0.012	0.474
d 0 to 43 (Overall)					
ADG, lb	0.92	0.93	0.96	0.016	0.109
ADFI, lb	1.32	1.31	1.35	0.019	0.340
F/G	1.45	1.43	1.42	0.014	0.060

[a-c]Means within row with different superscripts differ ($P < 0.05$).

[1]A total of 360 barrows (DNA 200 × 400; initial BW 12.4 ± 0.37 lb) were used in a 43-d experiment with 5 pigs per pen and 24 replications per allotment strategy. No interactions between allotment strategy and dietary treatment were observed.

[2]Pigs were allotted to pens in a completely randomized design.

[3]Pigs were sorted by body weight into five groups in the Microsoft Excel software program. Within each body weight group, pigs were randomized to pen such that each pen consisted of 1 random pig from each body weight group to ensure that distribution of body weights within pen was relatively consistent across pens.

[4]Pigs were sorted into three groups by body weight in the Microsoft Excel software program (light, medium, and heavy). Within each body weight group, pigs were randomized to pen such that each pen consisted of pigs from a single body weight group (pens of light pigs, pens of medium pigs, and pens of heavy pigs).

Table 3. Evaluation of carbadox and pharmacological levels of zinc and copper on growth performance of nursery pigs[1]

Item	Negative control[2]	Positive control[3]	SEM	*P* =
BW, lb				
d 0	12.4	12.4	0.349	0.900
d 8	13.4	14.1	0.309	0.020
d 15	17.1	19.3	0.291	< 0.001
d 22	21.6	26.2	0.348	< 0.001
d 29	28.3	35.4	0.404	< 0.001
d 36	37.5	45.5	0.453	< 0.001
d 43	48.8	57.0	0.534	< 0.001
d 0 to 22 (Phase 1)				
ADG, lb	0.41	0.61	0.026	< 0.001
ADFI, lb	0.56	0.72	0.016	< 0.001
F/G	1.40	1.18	0.040	< 0.001
d 22 to 43 (Phase 2)				
ADG, lb	1.30	1.47	0.014	< 0.001
ADFI, lb	1.95	2.18	0.021	< 0.001
F/G	1.51	1.48	0.010	0.078
d 0 to 43 (Overall)				
ADG, lb	0.84	1.03	0.013	< 0.001
ADFI, lb	1.24	1.42	0.016	< 0.001
F/G	1.48	1.39	0.012	< 0.001
Injections per 1,000 pig days				
Total injections	35.70	28.75	0.091	0.020
Baytril	30.05	24.90	0.098	0.060
Penicillin	5.64	3.84	0.240	0.114

[1]A total of 360 barrows (DNA 200 × 400; initial BW 12.4 ± 0.35 lb) were used in a 43-d experiment with 5 pigs per pen and 36 replications per dietary treatment.
[2]Negative control diets were formulated to meet NRC (2012) requirements for Zn (110 mg/kg) and Cu (17 mg/kg) with no addition of antibiotic.
[3]Positive control diets contained pharmacological levels of Zn (2,414 ppm from ZnO) in Phase 1 diet and Cu (168 ppm from $CuSO_4$) in both Phase 1 and Phase 2 diets. Both PC diets contained carbadox (50 g/ton; Mecadox, Phibro Animal Health, Teaneck, NJ).

Table 4. Evaluation of different allotment strategies on coefficient of variation[1]

Item	Random[2]	Body weight distribution[3]	Body weight grouping[4]
Within pen CV[5]			
d 0	14.7	15.7	6.2
d 8	16.0	17.1	8.9
d 15	15.9	17.8	10.1
d 22	15.5	16.0	9.8
d 29	15.9	16.7	10.3
d 36	14.9	15.1	9.4
d 43	14.4	13.7	9.1
Between pen CV[6]			
d 0	5.9	3.0	2.8
d 8	6.7	6.1	4.8
d 15	8.5	8.9	7.5
d 22	12.1	10.5	11.5
d 29	13.2	11.7	12.4
d 36	11.6	10.4	10.7
d 43	9.8	8.9	8.7
Population CV[7]			
d 0	15.0	14.7	14.9
d 8	16.3	17.1	16.1
d 15	17.6	19.0	17.9
d 22	19.2	19.0	18.4
d 29	20.2	19.5	18.1
d 36	18.4	17.3	15.6
d 43	17.3	15.5	14.0

[1]A total of 360 barrows (DNA 200 × 400; initial BW 12.4 ± 0.37 lb) were used in a 43-d experiment with 5 pigs per pen and 24 replications per allotment strategy.
[2]Pigs were allotted to pens in a completely randomized design.
[3]Pigs were sorted by body weight into five groups in the Microsoft Excel software program. Within each body weight group, pigs were randomized to pen such that each pen consisted of 1 random pig from each body weight group to ensure that distribution of body weights within pen was relatively consistent across pens.
[4]Pigs were sorted into three groups by body weight in the Microsoft Excel software program (light, medium, or heavy). Within each body weight group, pigs were randomized to pen such that each pen consisted of pigs from a single body weight group (pens of light pigs, pens of medium pigs, and pens of heavy pigs).
[5]Calculated by dividing standard deviation of pig weight within pen by the average weight of pigs within pen.
[6]Calculated by dividing standard deviation of pen mean body weight by the average of pen mean body weight.
[7]Calculated by dividing standard deviation of body weight of all pigs within allotment strategy by mean body weight of all pigs within that allotment strategy.

Table 5. Effects of allotment strategy on sample size per group required to detect statistically significant percent improvement in response[1]

	Improvement in response, %				
Item	**2%**	**4%**	**6%**	**8%**	**10%**
BW					
D 22					
Random[2]	240	60	27	15	10
Body weight distribution[3]	112	28	13	7	5
Body weight grouping[4]	114	29	13	8	5
D 43					
Random[2]	77	20	9	5	4
Body weight distribution[3]	93	24	11	6	4
Body weight grouping[4]	52	13	6	4	3
ADG (d 0 to 22)					
Random[2]	3,618	905	402	227	145
Body weight distribution[3]	942	236	105	59	38
Body weight grouping[4]	619	155	69	39	25
ADFI (d 0 to 22)					
Random[2]	1,705	427	190	107	69
Body weight distribution[3]	377	95	42	24	16
Body weight grouping[4]	418	105	47	27	17
F/G (d 0 to 22)					
Random[2]	823	206	92	52	33
Body weight distribution[3]	305	77	34	20	13
Body weight grouping[4]	209	53	24	14	9
ADG (d 22 to 43)					
Random[2]	138	35	16	9	6
Body weight distribution[3]	137	35	16	9	6
Body weight grouping[4]	69	18	8	5	3
ADFI (d 22 to 43)					
Random[2]	122	31	14	8	5
Body weight distribution[3]	175	44	20	11	7
Body weight grouping[4]	93	24	11	6	4
F/G (d 22 to 43)					
Random[2]	95	24	11	6	4
Body weight distribution[3]	54	14	6	4	3
Body weight grouping[4]	82	21	10	6	4

continued

Table 5. Effects of allotment strategy on sample size per group required to detect statistically significant percent improvement in response[1]

	Improvement in response, %				
Item	**2%**	**4%**	**6%**	**8%**	**10%**
ADG (d 0 to 43)					
Random[2]	295	74	33	19	12
Body weight distribution[3]	197	50	22	13	8
Body weight grouping[4]	141	36	16	9	6
ADFI (d 0 to 43)					
Random[2]	261	66	29	17	11
Body weight distribution[3]	182	46	21	12	8
Body weight grouping[4]	129	33	15	9	6
F/G (d 0 to 43)					
Random[2]	53	14	6	4	3
Body weight distribution[3]	67	17	8	5	3
Body weight grouping[4]	60	15	7	4	3

[1]A total of 360 barrows (DNA 200 × 400; initial BW 12.4 ± 0.35 lb) were used in a 43-d experiment with 5 pigs per pen and 24 replications per allotment strategy. Sample size calculations assume an α of 0.05 with 80% power. Values reported as number of pens per treatment to detect a statistically significant difference between treatments of indicated magnitude. Values reported within BW grouping strategy are values for numbers of pens total within each treatment group, not number of pens within each body weight group.
[2]Pigs were allotted to pens in a completely randomized manner.
[3]Pigs were sorted by body weight into five groups in the Microsoft Excel software program. Within each body weight group, pigs were randomized to pen such that each pen consisted of 1 random pig from each body weight group to ensure that distribution of body weights within pen was relatively consistent across pens.
[4]Pigs were sorted into three groups by body weight in the Microsoft Excel software program (light, medium, and heavy). Within each body weight group, pigs were randomized to pen such that each pen consisted of pigs from a single body weight group (pens of light pigs, pens of medium pigs, and pens of heavy pigs).