Kansas Agricultural Experiment Station Research Reports

Volume 2
Issue 8 *Swine Day*

Article 38

January 2016

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Recommended Citation

Holder, C.; Carpenter, C.; Tokach, M. D.; DeRouchey, J. M.; Woodworth, J. C.; Goodband, R. D.; and Dritz, S. S. (2016) "Effects of Increasing Space Allowance by Removing a Pig or Gate Adjustment on Finishing Pig Growth Performance," *Kansas Agricultural Experiment Station Research Reports*: Vol. 2: Iss. 8. https://doi.org/10.4148/2378-5977.1315

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Summary

A total of 256 pigs (PIC 327 × 1050; initially 123.1 lb) were used in a 71 d growth study to compare the effects of increasing space allowance by removing a pig or gate adjustment, on finishing pig growth performance. At the initiation of the trial, pens of pigs were blocked by BW and allotted to 1 of 4 space allowance treatments. The 4 treatments included: 1) 9.8 ft^2/pig or 2) 6.8 ft^2/pig for the entire study with treatments 3 and 4 initially providing 6.8 ft^2, but either a gate was adjusted or the heaviest pig in the pen was removed to provide more space. By using the following equation, space adjustments were made to keep the pigs above their predicted minimum space requirement before growth is impacted: space $[(m^2) = 0.0336 \times BW\ (kg)^{0.66}]$. There were initially 8 pigs per pen and 8 pens per treatment.

From d 0 to 28, before any gate adjustments or pig removals, ADG tended to be greater ($P = 0.076$) for pigs allowed 9.8 ft^2 compared with pigs stocked at 6.8 ft^2. Overall, d 0 to 71, pigs allowed 9.8 ft^2 had greater ($P = 0.001$) ADG compared with pigs with all other space allowances. Removing pigs or adjusting the gating increased ($P = 0.001$) ADG compared to those maintained at 6.8 ft^2; however, both treatments had decreased ($P = 0.001$) ADG compared with pigs allowed 9.8 ft^2. Most of the differences in ADG can be explained by differences in ADFI. Pigs allowed 9.8 ft^2 had greater ($P = 0.001$) ADFI compared with pigs allowed 6.8 ft^2; however, intake was similar for pigs allowed increased space by gate adjustment to pigs allowed 9.8 ft^2. Pigs allowed increased space by pig removal had similar ADFI to pigs allowed 6.8 ft^2. Space allowance did not influence feed efficiency.

In summary, as expected, pigs with 9.8 ft^2 grew faster and consumed more feed than pigs that were restricted in space. Furthermore, either removing a pig or adjusting the gating as pigs reached the critical k value influenced growth performance similarly. We speculated that along with pig growth, removing the heaviest pigs could have influenced social dynamics of the remaining pigs in the pen; however, our study indicates the performance benefit from removing the heaviest pig from the pen is primarily from

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the increased space allowance alone. As pigs grew to the minimum predicted space requirement and were subsequently allowed more space, performance was not similar compared to unrestricted pigs. This indicates the industry accepted minimum space prediction equation [$m^2 = 0.0336 \times BW (kg)^{0.66}$] doesn't fully explain the impacts on pig performance across multiple body weight ranges.

Key words: space allowance, K-value, marketing

Introduction

Facility space is the second largest cost of pig production and efficiently using the space is important to maintain profitable pork production. A common allometric expression has been used to describe the relationship between floor space and pig BW, similar to that used to describe volume and surface area. Gonyou et al. (2006)[2] used the allometric expression $A=k^*BW^{0.66}$, where A is area allowed per pig (m^2), k is a coefficient, and BW is pig weight (kg), which converts BW into a 2-dimensional concept, to describe floor space allowance in order to predict productivity. Using this k value, 0.0336, the equation should indicate when crowding begins to limit growth. Pig growth should not be decreased until their BW reaches the point where there is inadequate space to maintain maximal growth rate, (i.e., a k coefficient less than the critical k value; Gonyou et al., 2006).

A study by Flohr et al. (2015)[3] suggested reductions in growth due to inadequate space allowance may start to occur before pigs reach the critical k value. They also reported that removing pigs before the entire pen is marketed increases space allowance for remaining pigs in the pen and increases pig growth performance (Flohr et al., 2015). However, it has not been evaluated whether the improvements in growth are due to the change in social dynamic from removing the heaviest pig, or simply the increased space in the pen as a result of removing the heaviest pig. Thus, the objective of our study was to determine whether the increase in growth rate that occurs when pigs are removed from pens during marketing is due to increasing space allowance by pig removal or gate adjustment during the finishing period.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. The facility was totally enclosed and environmentally controlled, containing 32 pens. Pens were 8 × 10 ft, equipped with adjustable gates to allow different space allowances per pig, completely slatted floors and deep pits for manure storage. Each pen was equipped with a dry single-sided feeder (Farmweld, Teutopolis, IL) with two 14 × 10 in (width × depth)

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[2] Gonyou, H. W., M. C. Brumm, E. Bush, J. Deen, S. A. Edwards, R. Fangman, J. J. McGlone, M. Meunier-Salaun, R. B. Morrison, H. Spoolder, P. L. Sundberg, and A. K. Johnson. 2006. Application of broken-line analysis to assess floor space requirements of nursery and grower-finisher pigs expressed on an allometric basis. J. Anim. Sci. 84:229–235.

[3] Flohr, J. R.; Tokach, M. D.; Patience, John F.; Gourley, G.; DeRouchey, J. M.; Dritz, S. S.; Woodworth, J. C.; and Goodband, R. D. (2015). "Re-evaluating floor space allowance and removal strategy effects on the growth of heavyweight finishing pigs." Kansas Agricultural Experiment Station Research Reports: Vol. 1: Iss. 7.

feeder spaces and a 1-cup waterer, which provided ad libitum access to feed and water. A robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) was used to deliver and record daily feed additions to each individual pen.

A total of 256 pigs (PIC 327 × 1050; initially 123.1 lb) were used in a 71 d growth study. Pens of pigs were blocked by BW and allotted to 1 of 4 space allowance treatments, initially with 8 pigs per pen (4 barrows and 4 gilts) and 8 pens per treatment. The 4 treatments included pens with 9.8 ft^2/pig or 6.8 ft^2/pig for the entire study. Two additional treatments initially provided 6.8 ft^2, but either a gate was adjusted on d 28, 45, and 62 or the heaviest pig in the pen was removed from the pen on d 28 and 45 to provide more space (Table 1). The space adjustments and pig removals were made to keep the pigs above their predicted minimum space requirement [$(m^2) = 0.0336 \times BW\ (kg)^{0.66}$], where 0.0336 is the *k* value. If a pig died or was removed from a pen during the experiment, pen size was adjusted to maintain the correct space allowance per pig.

Pigs were fed a common corn-soybean-meal based diet offered in 3 phases (Table 2). Diets were formulated to meet or exceed the pigs' nutrient requirement estimates (NRC, 2012)[4] and the 3 phases were fed from approximately 123 to 185, 185 to 220, and 220 to 280 lb BW. Diets were sampled and subsamples were sent to a commercial laboratory (Ward Laboratories Inc., Kearney, NE) for analysis (DM and CP; Table 2). Pens of pigs and feeders were weighed on d 0, 14, 28, 45, 62, and 71 to calculate ADG, ADFI, and F/G.

Data were analyzed as a generalized randomized block design with space allowance treatment as a fixed effect and block as a random effect using PROC MIXED in SAS (SAS Institute, Inc., Cary, NC), with pen serving as the experimental unit. Treatment means were separated using the DIFFS option from the LSMEANS statement of SAS. Results were considered significant at $P \le 0.05$ and a tendency at $P > 0.05$ and $P \le 0.10$.

Results and Discussion

From d 0 to 14, there was no effect of stocking density observed for ADG, ADFI, and F/G, which corresponded to a change in BW from approximately 123 to 153 lb (Table 3). From d 14 to 28, pigs provided 9.8 ft^2 had increased ADFI ($P = 0.041$) and ADG ($P = 0.002$), which resulted in improved F/G ($P = 0.025$) and a tendency for increased ($P = 0.081$) BW, compared to pigs provided 6.8 ft^2. These observations suggest space restriction started to influence growth rate between 153 and 182 lb BW. Based on a *k* value of 0.0336, no differences in pig performance were expected before d 28 which corresponded to BW of approximately 182 lb. From d 0 to 28, before any gate adjustments or pig removals, ADG tended to be greater ($P = 0.076$) for pigs allowed 9.8 ft^2 compared to pigs stocked at 6.8 ft^2 for the duration of the study.

From d 28 to 45, pigs provided 6.8 ft^2 or increasing space allowance by removal of the heaviest pig, had decreased ($P = 0.025$) ADFI compared to pigs provided 9.8 ft^2 with pigs from pens where the gate was adjusted being intermediate. This suggests when the heaviest pig is removed from a pen, pigs did not maintain feed intake similar to pigs allowed 9.8 ft^2.

[4] NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Natl. Acad. Press, Washington, D.C.

From d 45 to 62, ADFI was decreased ($P = 0.001$) for pigs provided 6.8 ft^2 compared to all other treatments. During this period, increasing space allowance resulted in performance similar to pigs allowed 9.8 ft^2. On d 62, gates were adjusted to reach the desired k value; however, a pig was not removed from the pig removal treatment because the critical k value was reached sooner based on the actual ft^2 for pigs in the gate adjustment treatment than for the pig removal treatment.

From d 62 to 71, ADG decreased ($P = 0.008$) when pigs were allowed 6.8 ft^2 compared to all other treatments, which is likely due to the decreased ($P = 0.001$) ADFI, because F/G was not affected.

For the cumulative period after space adjustments began (d 28 to 71), both ADG and ADFI decreased ($P = 0.001$) when pigs were provided 6.8 ft^2 compared with pigs provided 9.8 ft^2. Pigs provided increased space by removing pigs had similar performance to those where gates were adjusted to increase space; however, pig removal resulted in lower ADG and ADFI than pigs allowed 9.8 ft^2 throughout the experiment.

Overall (d 0 to 71), pigs provided 9.8 ft^2 had increased ($P = 0.001$) ADG compared with all other treatments. Performance of pigs with gate adjustment or pig removal was similar, and both having greater ADG than pigs provided 6.8 ft^2. Pigs provided 9.8 ft^2 had increased ($P = 0.001$) ADFI compared with pigs allowed 6.8 ft^2; however, intake was similar among pigs provided increased space by gate adjustment to pigs allowed 9.8 ft^2. Pigs provided increased space by pig removal had similar ADFI to pigs allowed 6.8 ft^2. Final BW was decreased ($P = 0.001$) for pigs provided 6.8 ft^2 compared with those provided 9.8 ft^2. Also, final BW of pigs provided increased space by adjusting the gate was greater ($P = 0.001$) than pigs allowed 6.8 ft^2 or increased space by pig removal, but decreased ($P = 0.001$) compared to pigs provided 9.8 ft^2.

Gonyou et al. (2006) reported that ADFI was decreased when pigs were stocked below a critical k value of 0.0336, which is also supported by our study. Reductions in performance have been observed due to inadequate space allowance, which may start to occur before the pigs reach their critical k value. This is a similar key finding in our study where pig performance was reduced before the critical k value was reached, which confirms recent research of Flohr et al. (2015). Furthermore, our data suggest improved growth performance after pigs are removed during the finishing period may be largely due to the increased space provided to pigs remaining in the pens because performance was similar to that of pigs where space was increased by adjusting the gate (without removing the heaviest pig).

In this study, pigs with greater space allowance grew faster and consumed more feed than pigs that were restricted in space. Furthermore, either removing a pig or adjusting the gating as pigs reached the critical k value influenced growth performance similarly. We speculated that along with pig growth, social dynamics of the remaining pigs in the pen could have been influenced by removing the heaviest pigs; however, our study indicates the performance benefit from removing the heaviest pig from the pen is primarily from the increased space allowance alone. Lastly, as pigs grew to the minimum predicted space requirement and were subsequently provided more space, performance was not similar to unrestricted pigs. Increasing the space allowance by removing pigs or adjusting the gating increased ADG compared to pigs provided 6.8 ft^2 for the entire experiment; however, neither treatment allowed pigs to maintain ADG similar to pigs provided 9.8 ft^2 throughout the study. This indicates the industry accepted minimum space prediction equation [(m^2) = 0.0336 × BW (kg)$^{0.66}$] doesn't fully explain impacts on pig performance across multiple body weight ranges.

Table 1. Space allowance and *k* value through the experiment[1]

Item	9.8 ft^2	6.8 ft^2	Gate adjustment[2]	Pig removal[3]
d 0				
ft^2/pig[4]	9.8	6.8	6.8	6.8
k value[5]	0.0615	0.0427	0.0427	0.0427
d 28				
ft^2/pig	9.8	6.8	7.8	7.8
k value				
Before adj.	0.0473	0.0328	0.0377	0.0377
After adj.	---	---	0.0425	0.0439
d 45				
ft^2/pig	9.8	6.8	8.8	9.1
k value				
Before adj.	0.0422	0.0293	0.0379	0.0392
After adj.	---	---	0.0422	0.0392
d 62				
ft^2/pig	9.8	6.8	9.8	9.1
k value				
Before adj.	0.0368	0.0255	0.0368	0.0342
After adj.	---	---	0.0368	0.0409
d 71				
ft^2/pig	9.8	6.8	9.8	9.1
k value	0.0361	0.0250	0.0361	0.0335

[1]A total of 256 pigs (PIC 327 × 1050, initially 123.1 lb) were used in a 71 d growth trial. Average BW on d 0, 28, 45, 62 and 71 was 123, 182, 216, 265, and 273 lb, respectively.
[2]Increased space by gate adjustment (d 28, 45, and 62).
[3]Increased space by heaviest pig removal (d 28 and 45).
[4]Indicates area maintained (ft^2/pig) between each data collection period.
[5]*k*-value [(m^2) = *k* × BW (kg)$^{0.66}$] calculated before and after a pig was removed or gates were adjusted.

Table 2. Diet composition (as-fed basis)

	Phase[1]		
Ingredient, %	1	2	3
Corn	71.50	78.44	82.86
Soybean meal, 47.7% CP	25.71	19.20	14.93
Monocalcium P, 21% P	0.55	0.33	0.30
Limestone	1.13	1.10	1.08
Salt	0.35	0.35	0.35
L-Lys HCl	0.31	0.25	0.22
DL-Met	0.06	0.02	---
L-Thr	0.09	0.05	0.05
Trace mineral premix	0.15	0.13	0.10
Vitamin premix	0.15	0.13	0.10
Phytase[2]	0.02	0.02	0.02
Total	100.00	100.00	100.00
Calculated analysis			
Standardized ileal digestible (SID) AA's, %			
Lys	1.05	0.85	0.72
Ile:Lys	62	64	66
Met:Lys	30	29	30
Met and Cys:Lys	55	56	59
Thr:Lys	61	61	64
Trp:Lys	18.0	18.0	18.0
Val:Lys	69	73	76
Total Lys, %	1.18	0.96	0.82
ME, kcal/lb	1,494	1,501	1,504
NE, kcal/lb	1,117	1,137	1,150
SID Lys:ME, g/Mcal	3.19	2.57	2.17
CP, %	18.5	15.9	14.2
Ca, %	0.62	0.55	0.52
P, %	0.49	0.41	0.39
Available P, %	0.29	0.23	0.22
Chemical analysis[3], %			
DM	88.32	87.25	87.41
CP	18.5	15.4	14.8

[1]Phases 1, 2, and 3 were fed d 0 to 28, 28 to 45, and 45 to 71, respectively.
[2]HiPhos (DSM Inc, Parsippany, NJ) provided 1,228,503 (FYT)/lb of product and released 0.10% available P.
[3]Multiple samples of each diet were collected, blended and subsampled, and analyzed (Ward Laboratories, Inc. Kearney, NE). Values are represented on an as fed basis.

Table 3. Effects of pig space allowance on finishing pig growth performance[1,2]

Item	9.8 ft²	6.8 ft²	Gate adjustment[3]	Pig removal[4]	SEM	*P* <
BW, lb						
d 0	123.3	123.4	123.2	122.6	0.33	0.361
d 14	152.3	152.6	153.0	152.3	0.57	0.835
d 28	185.3[x]	181.5[y]	182.1[y]	182.6[y]	1.03	0.081
d 45	221.8[a]	214.5[b]	216.5[b]	214.8[b]	1.07	0.001
d 62	261.4[a]	252.5[c]	256.8[b]	251.4[c]	1.39	0.001
d 71	280.6[a]	268.3[c]	275.4[b]	270.0[c]	1.60	0.001
d 0 to 14						
ADG, lb	2.07	2.08	2.13	2.13	0.032	0.495
ADFI, lb	4.83	4.75	4.83	4.84	0.097	0.894
F/G	2.33	2.28	2.27	2.28	0.045	0.752
d 14 to 28						
ADG, lb	2.32[a]	2.06[b]	2.08[b]	2.15[b]	0.045	0.002
ADFI, lb	5.70[a]	5.32[b]	5.51[b]	5.60[b]	0.091	0.041
F/G	2.45[a]	2.57[b]	2.65[b]	2.60[b]	0.047	0.025
d 0 to 28						
ADG, lb	2.19[x]	2.07[y]	2.10[xy]	2.14[xy]	0.033	0.076
ADFI, lb	5.27	5.03	5.17	5.22	0.078	0.200
F/G	2.40	2.43	2.46	2.44	0.033	0.541
d 28 to 45						
ADG, lb	2.15	1.94	2.02	2.06	0.061	0.143
ADFI, lb	6.32[a]	5.93[b]	6.14[ab]	5.90[b]	0.102	0.025
F/G	2.96	3.08	3.05	2.87	0.080	0.240
d 45 to 62						
ADG, lb	2.33	2.24	2.38	2.32	0.049	0.260
ADFI, lb	7.06[a]	6.40[b]	6.96[a]	6.87[a]	0.100	0.001
F/G	3.03	2.87	2.94	2.98	0.056	0.237
d 62 to 71						
ADG, lb	2.12[a]	1.75[b]	2.06[a]	2.06[a]	0.077	0.008
ADFI, lb	6.43[a]	5.88[b]	6.56[a]	6.46[a]	0.101	0.001
F/G	3.07	3.39	3.20	3.16	0.127	0.334

continued

Table 3. Effects of pig space allowance on finishing pig growth performance[1,2]

Item	9.8 ft^2	6.8 ft^2	Gate adjustment[3]	Pig removal[4]	SEM	P <
d 28 to 71						
ADG, lb	2.21^a	2.01^c	2.17^{ab}	2.15^b	0.029	0.001
ADFI, lb	6.64^a	6.10^c	6.55^{ab}	6.37^b	0.077	0.001
F/G	3.00	3.03	3.02	2.96	0.033	0.441
d 0 to 71						
ADG, lb	2.21^a	2.04^c	2.14^b	2.15^b	0.021	0.001
ADFI, lb	6.09^a	5.68^c	6.01^{ab}	5.85^{bc}	0.063	0.001
F/G	2.76	2.81	2.82	2.77	0.030	0.486

[1]A total of 256 pigs (PIC 327 × 1050; initially 123.1 lb) were used in a 71 d growth trial with 8 replications/treatment to determine the effects of space allowance on finishing pig growth performance.
[2]Means within a row with different superscripts differ: ^{abc} P < 0.05, ^{xyz} P < 0.10
[3]Increased space = increased gate adjustment; initially 6.8 ft^2/ pig with gates adjusted as pigs reached the *k* value, to be non-limiting (7.8 ft^2 at 180 lb (d 28), 8.8 ft^2 at 220 lb (d 45), and 9.8 ft^2 at 260 lb (d 62)).
[4]Increased space = removal of heaviest pig; initially 6.8 ft^2/ pig with a pig removed as the *k* value is reached to be non-limiting: 1 pig at 180 lb (d 28) and 220 lb (d 45).