Pig performance comparing a production system using large static groups formed during lactation to a production system using sized and resorted groups in nursery and finisher

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Summary
Groups of 95 pigs commingled during lactation (G) were compared to similar-sized groups from crates that were sorted into eight nursery pens or four finishing pens (P). System differences contributed to a trend for improved feed:gain (1.479 G, 1.696 P; SE = 0.074; P =.09) in the G nursery.

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Common swine production practice weans all piglets from a farrowing group into a nursery or wean-to-finish facility that houses them in groups of 20 to 40, sorted by sex and size. Feed rations may be adjusted for size and sex when animals are sorted into pens, but the use of only one or two bulk bins limits the ability to match feed rations to different pens. Small farrow-to-finish operations with 300 sows produce about 60 barrows and 60 gilts each week. Sorting this number of animals into pens does not require a significant increase in labor. However, new, larger farrowing operations often have 1200 to 5000 sows, and sorting 500 to 2000 pigs per week into uniform groups of 20 to 40 animals is a very significant chore. Despite the change in farrowing scale, practice and supporting research has remained focused on management methods for small groups of pigs in both nursery and finishing phases.

The interactions between environmental factors (eg, number of available feeders and waterers and thermal environment) that make studying animal space requirements interesting also make comparing production in different group sizes challenging. Many studies on group size have included production comparisons of animal space allowances, with sometimes contradictory results.[1–5] It is plausible that limited space or other limited resources also contributed to many of the negative production results reported. Production tests comparing only the number of pigs in a pen also had contradictory results.[6–10] Chapple[2] summarized these conflicting results by noting that space allocation is more important than group size, but pig growth rates, feed intakes, and carcass lean percentages also may be suppressed as group size increases from one to 36 animals. The empirical equations used and relatively small group sizes in many of these production tests do not allow good predictions for larger groups: results from several studies cited here and by Chapple predict negative intakes and gain when extrapolated to groups of more than 80.

The act of regrouping animals also reduces gain and feed intake in thermally stressed swine.[11] Recent regulations in the European Union try to limit mixing stress by permitting animal regroupings for no longer than 1 week after weaning. Other proposed regulations to limit the use of crates for sows to 1 week before and after farrowing have led many European producers to mix sows and litters in an open lactation room 1 week after farrowing.[12] The commingled piglets from one lactation room are retained in the same group through the nursery and finishing production phases.

The objective of this study was to determine whether commingling 100 pigs (12 litters) during lactation and maintaining them in a single group has any significant performance advantages in the nursery and finishing rooms compared to sorting and penning groups of 12 pigs by size in the nursery and re-mixing them in groups of 24 in finishing facilities.

Materials and methods

Pigs
All animals were born and tested on the 300-sow, farrow-to-finish Osborne Demonstration Farm located near Osborne, Kansas. Piglets were assigned to treatments (penned or group-housed) depending on the type of farrowing room they were born in.[13,14] Sows were assigned to farrowing rooms as part of a study comparing management of sows in group housing, with electronic sow feeding for gestation and farrowing, to management of sows in gestation and farrowing crates. Management was similar in the two systems: the pigs were of the same genetic type, the same managers cared for all animals, and similar thermal environments, feeds, and health treatments were provided during lactation, nursery, and finishing stages. Despite efforts to standardize animal management, several production aspects, such as average sow parity, the number of pigs per group, and average weaning weight, differed between treatments as a natural result of production system differences. Details of these system differences are reported elsewhere.[15]

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Housing

Penned pigs. The approximately 100 penned-treatment (P) animals in each replication (trial) were born to sows housed in individual crates in a 12-crate farrowing room. The dams gestated and farrowed in crates throughout their productive life as part of another test.[13,14] Each trial group of P pigs was placed at weaning into eight pens in a nursery room (Figure 1). One of four different nursery rooms was used for each trial group, with room assignments based on available space as dictated by production schedules. Each nursery room contained eight pens (1.83 m × 2.74 m), allowing a minimum of 0.30 m^2 per animal for a pen of 17 pigs and 0.56 m^2 for a pen of nine pigs. Each pen had 0.836 m^2 of temperature-controlled heating pads (Stanfield; Osborne Industries Inc), one nipple waterer, and access to one half of a round fence-line nursery feeder (Big-Wheel RN3; Osborne Industries Inc) with five feeder spaces per pen. Nursery rooms were mechanically ventilated with pit fans and additional wall fans for summer ventilation.

Each trial group of P pigs moved from a nursery room was resorted by size into four pens (3.65m × 6.25 m) on one side of a finishing room (the other side of the finishing room housed group-housed pigs in the same trial; Figure 1). Each side of the room had three eight-hole round feeders (Big Wheel RF1; Osborne Industries, Inc) and eight nipple waterers. For the P pigs, there were two nipple waterers in each pen, two feeders were freestanding in the middle of their respective pens, and the third fence-line feeder was shared between two pens. Space allowance for the P pigs ranged from 0.89 m^2 at 28 pigs per pen to 1.08 m^2 at 21 pigs per pen. Finishing rooms were mechanically ventilated, with supplemental misting and sprinkling for hot weather. All finishing floors were concrete slats.

Group-housed pigs. The approximately 100 group-housed (G) pigs in each trial were born in an open-housed, 12-sow farrowing room where sows were individually fed with an electronic sow feeder (ESF) (TEAM F-Station; Osborne Industries Inc). The sows gestated in large pens with ESF and farrowed in the open-housed farrowing rooms with ESF throughout their productive life, as part of another test.[14] The G pigs were intermingled in the farrowing room within 1 week of birth and remained in the same group through lactation, nursery, and finishing stages.

At weaning, a trial group of G pigs were placed into a nursery room similar to the P pigs but with penning removed (Figure 1). One of three G nursery rooms was used for each trial group, with room assignments based on available space of the appropriate room type as dictated by production schedules. Removing the penning utilized the alleyway and increased usable space per room from 40.1 m^2 to 46.8 m^2 (0.48 to 0.66 m^2 per pig). Each room contained three ten-space feeders (Big-Wheel RN3; Osborne Industries Inc) and eight wall-mounted nipple waterers. In the first trial, the G nurseries had four heating pads (Stanfield), with two (each 1.67 m^2, total area 3.34 m^2) in opposite corners on the short (4.27 m) side of the nursery room. In subsequent trials, heating pads were provided in only one corner of the room.

A trial group of G animals was moved from a nursery to one half of a finishing room, across a central alleyway from P pigs in the same trial (Figure 1). This half of the room was modified for the G pigs by removal of the pen dividers, allowing both treatment groups to be assigned to the next one of eight identical finishing rooms available according to normal animal flow. The G pigs were provided with three eight-hole round feeders (Big Wheel RF1; Osborne Industries Inc) and eight nipple waterers, and had 0.95 m^2 to 1.25 m^2 of space per pig.

Study design

Five trial replications over time were used to compare the nursery production phase. As the pigs in two trials were used for other experiments in finishing, the finishing phase was compared in only three trials.

Pigs were obtained from contemporary farrowing groups of nine to 12 sows that farrowed in the same farrowing room during a single week. The two treatment groups within a trial came from successive farrowing groups from an open-housed farrowing room (G pigs) or from a crated farrowing room (P pigs). Pigs were weaned at 14 to 21 days, depending on birth date, with an average weaning age of 19 days. Pen weights were recorded when animals entered the nursery.

Group G pigs remained in the same contemporary group in a nursery room with no pen dividers. Group P pigs were sorted by size into eight nursery pens at weaning, and were individually weighed when moved to the finishing facility. Both groups spent 31 to 51 days in the nursery, and, in each trial, the P group and G group were moved to a single finishing room on the same day. As the P and G pigs had been moved into the nurseries from successive farrowing groups, there was a 1-week difference in the ages of the G and P pigs in the finishing room. The P pigs were resorted by size into four finishing pens on one side of a finishing room. In each trial, all G and P pigs were weighed individually, and the trial concluded for both groups on the day when the first pigs were ready for market.

Calculations

Average daily gain (ADG) was computed by dividing the average animal weights by the number of days between entry and exit dates for the nursery and finishing phases.

The amount of feed delivered to the nursery rooms was recorded. Average daily feed intake (ADFI) for the nursery was calculated from the total feed delivered divided by the days in the nursery and by the number of pigs in the group at the end of the nursery period. Feed conversion (FC) in the nursery was calculated by dividing ADFI by ADG.

Statistical analysis

A randomized block analysis of variance (ANOVA) was used to compare mean ADG, ADFI, and FC of farrowing groups in the nursery. Blocking consisted of a pair of treatment groups (trial), with replications being different trials repeated over time. The time each individual group of animals stayed in the nursery varied to meet production schedules, so a covariate of time in the nursery was added to analyze the nursery data.

A block ANOVA was used to compare ADG in finishing. Blocking was the same pair of trial groups (trial), with a trial being finished together in one finishing room, while replications were in different finishing rooms at different times.

The treatment coefficients of variation (CV=s/x) of individual weights within a trial as animals left the nursery and at market weight were compared using a randomized block ANOVA, similar to the finishing ADG analysis.

The D'Agostino test for skew[16] was used to identify individual treatment groups that had non-normal distributions. The D'Agostino test evaluates normality by comparing the skewness coefficient to the expected value of zero for large data sets (n>8 measures).

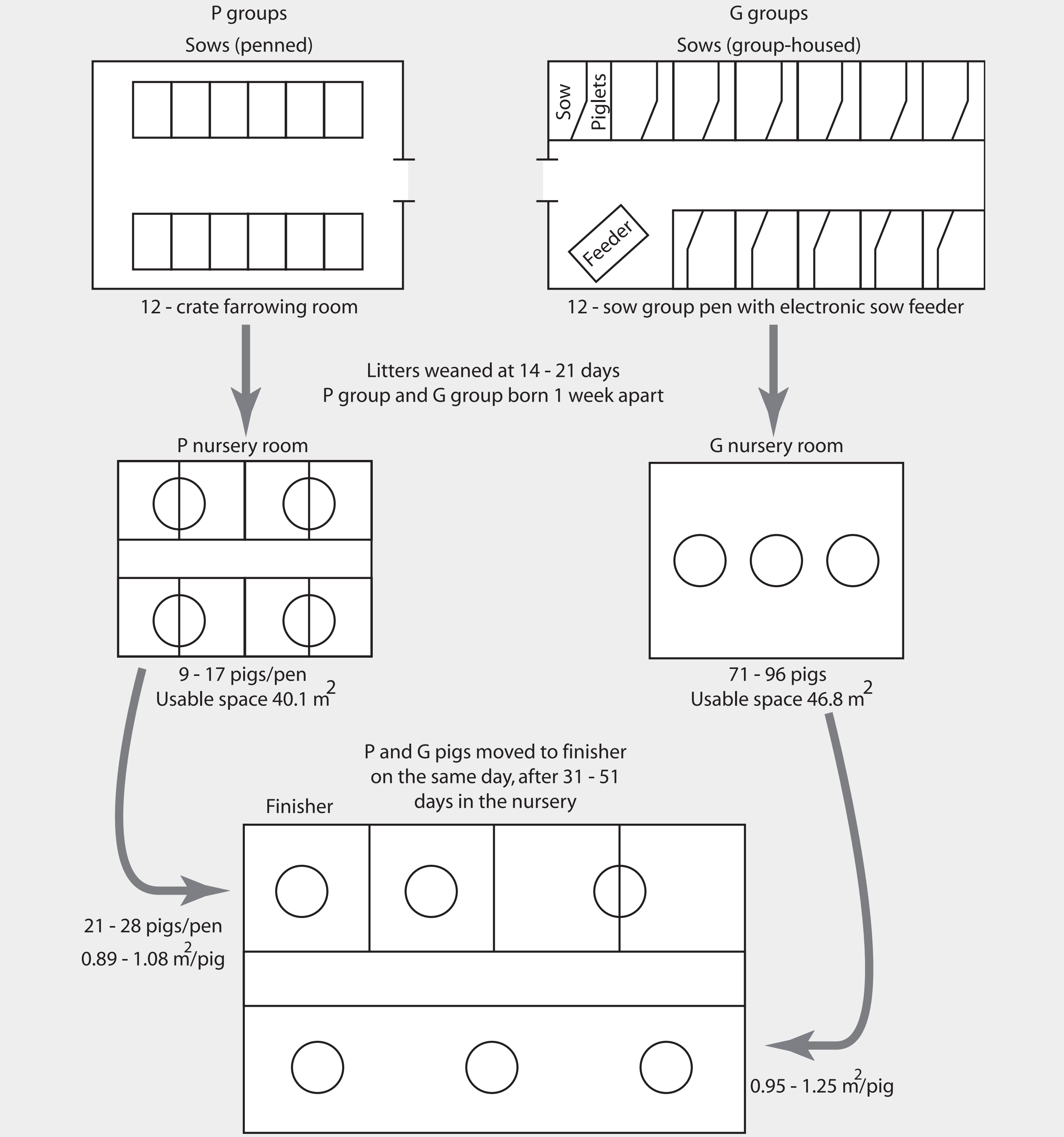
Results

Nursery phase

Pigs preferred to lie together in one corner of the G nursery rooms, regardless of the size of the group, and defecated in the other three corners of the room. In the second and subsequent trials, two unused heating pads were removed from one corner of the room with no noted adverse affects.

Mortality was too low to make a statistical comparison between treatments. Of the 956 pigs that entered the nursery, six died: two of the 422 G pigs and four of the 534

Figure 1: Pig flow from farrowing rooms to finisher, showing arrangement of pens and feeders for P groups (born to sows in farrowing crates, sorted into nursery pens at weaning, and resorted by size into finisher pens) and G groups (born to sows in open-housed farrowing rooms, commingled in the farrowing room at 1 week of age, housed together in a single nursery room at weaning, and moved into a single finisher pen). Circles represent feeders. Rooms and feeders are not to scale.



P pigs. Of the 538 study pigs that entered the finishing facility, four died: two of the 263 G pigs and two of the 275 P pigs.

Mean, CV, and skew of individual animal weights are shown in Table 1. Because of production differences in the number of sows farrowed, different numbers of pigs were used among treatment groups and between pairs of groups within a trial (Table 1). The mean weaning weight for the G pigs was less than that of the P pigs, but when they were moved to the finishing rooms, the mean weight of the G pigs was similar to that of the P pigs (Table 1). Mean weights for the two treatments remained similar as pigs approached market weight (Table 1).

The data from five trials were used to analyze nursery ADG, ADFI, and FC. As blocking was not significant for any of these traits, it was removed from the analysis to improve the ability to distinguish between treatments. Results of the covariate analysis for time in the nursery for ADG, ADFI, and FC are given in Table 2. No significant differences were found for ADG or ADFI. Feed conversion tended to be lower for the G pigs (Table 2). The time covariate analysis suggested that FC decreased with the increasing time in the nursery by 14.1 g feed per (kg BW × day) (P =.08.) Analysis was repeated with weaning weight and days in the nursery as covariates. Significance probability values for weight covariate coefficient (C) using the ANOVA model

$$Y_{ij}=\mu=B(X_{ij}-\bar{X})+C(W_{ij}-\bar{W})+t_j+e_{ij}$$

for the dependent variable ADG was P=.68, for ADFI was P=.39, and for FC was P=.33. The high P values indicate that weaning weight was not significant for the performance measures tested.

Coefficient of variation for the G treatment (17.4%) was similar to the CV for the P treatment (16.6%) at the end of the nursery phase (P=.13).

Finishing phase

Only three trial replications were analyzed for the finishing phase. Mean ADG was similar among blocks in the finishing phase, and blocking was removed from the analysis to improve the ability to distinguish between treatments. Mean ADG was similar between treatments (P>.10) for the 261 G pigs (0.934 kg per day) and 273 P pigs (0.890 kg per day).

Blocking was not significant for the CV during the finishing phase, and was again removed from the analysis to improve the ability to distinguish between treatments. Coefficient of variation was similar (P=.61) between the G (CV=10.2%) and P (CV=9.7%) treatments at the end of the finishing phase. When pigs were moved to the finishing facility, their average weight was 24 kg (SD=4.3 kg); when the first pigs were reaching market weight, the pigs averaged 97 kg (SD=9.7 kg). No trial replications of the G treatment were significantly skewed when tested by the D'Agostino test of skewness,[16] but three of the five P treatment trials were skewed (two at P<.05, and one at P<.001) at the move to grow-finish (Table 1). One of the three P treatment trials was skewed (P<.001) at market weight (Table 1).

Discussion

The differences between the numbers of pigs in the P and G production systems used in this test and the differences in length of nursery stay make it very difficult to compare treatments or identify causes of performance differences. Numbers of pigs in the treatment groups were constrained by the flow requirements and numbers of pigs farrowed in each group within this production situation. Alternatives to this production test also have drawbacks. Stan-

Table 1: Mean, coefficient of variation (CV), and skew of individual animal weights for groups of 71 to 96 pigs either socialized by 1 week of age and all penned together in nursery and finishing rooms (G pigs) or weaned from individually crated litters and regrouped by size into eight nursery and four finishing room pens (P pigs).

Parameter	Trial 1		Trial 2		Trial 3		Trial 4		Trial 5	
	G pigs	P pigs	G pigs	P pigs	G pigs	P pigs	G pigs	P pigs	G pigs	P pigs
No. of pigs moved to finisher	73	101	94	87	86	133	71	122	96	87
Weaning weight (kg)[1]	3.51	5.7	4.51	4.89	3.94	6.18	4.98	6.44	5.08	5.12
Move-to-finisher weight (kg)[2]	21.7	17.7	23.9	29.9	24.4	31.8	22.2	27.2	20.3	27.3
CV (%)	14.5	19.7	16.7	14.8	18.0	14.7	14.0	13.0	23.8	20.8
Skew	0.05	-0.63[3]	-0.38	-0.96[4]	-0.16	-0.22[3]	-0.39	-0.14	-0.16	-0.47
Days in nursery	49	41	44	51	42	49	37	44	37	44
Market weight (kg)[5]	99.9	95.3	96.6	104	NA[6]	NA	NA	NA	91.7	95.1
CV (%)	9.35	10.0	8.84	9.37	NA	NA	NA	NA	12.4	9.82
Skew	-0.16	-1.19	-0.23	-0.36	NA	NA	NA	NA	-0.29	-0.26

1 Mean weaning weight of the 422 G pigs (4.4 kg) was significantly less (P=.02, SE=0.45) than that of the 534 P pigs (5.7 kg).

2 Mean weights of the 420 G pigs (22.5 kg) (P=.13, SE=1.79) and the 530 P pigs (26.8 kg) did not differ when they were moved to the finisher.

3 D'Agostino[16] test of skewness significant non-normality at P<.05.

4 D'Agostino[16] test of skewness significant non-normality at P<.001.

5 Mean market weights of the 261 G pigs (96.1 kg) and the 273 P pigs (98.1 kg) did not differ (P=.61, SE=2.58).

6 NA= not applicable. These groups were not included in the study during the finishing phase.

Table 2: Nursery production parameters for groups of 71 to 96 pigs commingled by 1 week of age and penned together (G pigs) or weaned from sows in farrowing crates and sorted into pens of 10 to 17 pigs (P pigs).[1]

Production parameter[2]	G pigs	P pigs	SE	Treatment significance (*P* value)	Time covariate significance (*P* value)
ADG (kg/d)	0.455	0.434	0.033	.22	.63
ADFI (kg/d)	0.653	0.745	0.047	.66	.22
FC	1.479	1.696	0.074	.09	.08

1 Five replicate trials were conducted, and mean parameters were compared using a randomised block analysis of variance (ANOVA) .

2 ADG = (average weight at end of nursery period - average wean weight)/days in nursery; average daily feed intake (ADFI) = total feed / (no. of pigs moved to the finisher × days in nursery); feed conversion (FC) = ADFI/ADG.

dardizing on a group of 96 pigs (ie, 12 pigs per nursery pen in the P groups) would have required additional farrowing capacity and finding an alternative place to care for the excess pigs from each treatment group. Differences in weaning weight and preweaning mortality between an open-housing facility and a crated farrowing room are inherent to the different systems, but the pre-weaning commingling of G pigs in different litters was an essential treatment difference between the production systems being evaluated.

Rooms housing the large G nursery groups had three feeders compared to four in the P rooms. The G nursery rooms provided a minimum of one feeder space per 3.2 pigs. In Trial 3, there was a maximum of 18 P pigs per pen, or a minimum of one feeder space per 3.6 pigs. However, both treatments were well above the recommended values of one feeder space per five pigs.[17]

The eight waterers in the G nursery rooms provided a minimum of one waterer per 12 pigs, compared to recommendations of one waterer per 15 pigs.[17] In Trial 4, there were 16 P pigs per nursery pen in two pens, and in Trial 3, there were 16 or 17 pigs in all nursery pens. The use of only one waterer per nursery pen and the higher numbers of pigs per pen during Trials 3 and 4 in the P treatment may have affected drinking behavior and the related feed intake and growth.

The nurseries had more space for G animals (46.8 m^2 total) than for the P animals (40.1 m^2 total) because no alleyway was needed between pens. Space per animal in the nursery (minimum 0.30 m^2 per pig,) and finishing rooms (minimum 0.89 m^2 per pig) was above normally accepted values[17] and should have minimized the effect of different floor space allowance per pig.

Statistically insignificant differences in ADFI and ADG were reflected in a tendency for improved FC in the G nursery. The tendency for better group FC in the nursery may have originated in the differences between the crated and the open-housed farrowing systems. The lower mean weaning weight of the G pigs may have contributed to the lower FC in the G nurseries; different weaning weights were confounded with treatments in this test. The mixing of large and small animals and the higher average number of animals per feeder space in the G group also may have contributed to the lower FC in the nursery. As the ADFI was similar in P and G groups, and G animals had fewer feeders, the G pigs must have emptied the feed troughs faster. As swine are highly sensitive to molds and spoilage, reducing the time that feed remains in the feeder may improve feed consumption in recently weaned pigs.[3,9,10,18–20]

Similar improvements in FC were noted by McConnell et al[7] but these results differ from those of Wolter et al,[9,10] Kornegay and Notter,[15] and Verdoes et al.[12] In the study by Wolter et al,[9,10] ADFI and ADG were lower during the 4 weeks after weaning for groups of 100 weanling pigs compared to groups of 20 weanling pigs. In Wolter's study, there was consistently one feeder space per five pigs,[9] while the present study provided one feeder space per 2.4 to 3.6 pigs. Group-housed animals in this study had already been commingled, while animals in both of Wolter's tests were subject to additional regrouping stress at weaning. In these and other studies, the early productivity advantages became insignificant by the time the animals had reached market weight.[3,10,19-21] Verdoes et al[12] also noted that mixing pigs after weaning probably caused the decreases in ADG and ADFI observed before 69 days of age. In agreement with this study and that of Wolter et al,[10] the study of Verdoes et al[12] found that pigs maintained in a static group of 90 pigs in one room until market weight compensated for the lower early gain and had better carcasses, resulting in 3.34 EUR more profit per pig than when pigs were maintained in groups of ten.

If larger animals in a group had been displacing smaller animals at feeders or waterers, there would have been more "tail-enders"; ie, the skew and variation in weights would have been greater in that group. Visual comparisons incorrectly suggested that there was more size variability in the G animals than in the P animals. Large and small animals were commingled in the G groups, but were housed in different pens at opposite ends of the room in the P groups. Statistical measures were necessary to demonstrate that the variability within trial groups was similar between treatments. Coefficient of variation for the G treatment (17.4%) was similar to that for the P treatment (16.6%) at the end of the nursery phase (P=.13), and was also similar between the G (CV=10.2%) and P (CV=9.7%) treatments at the end of the finishing phase (P=.61). Considering the large variation in CV among sets of animals (Table 1), it is unlikely that the 5% relative differences between mean treatment CVs can be differentiated with fewer than ten replications.

D'Agostino[16] tests of animal weights found that three of five P treatment groups at the move out of the nursery and one of three finishing treatment groups of P pigs at market weight had statistically significant negative skew coefficients, suggesting that the P groups had more "tail-ender" pigs than the G groups.

Consideration of group weight variation is important in the marketing and management of animals. Proper selection of marketing dates based on true group weight and weight distribution may provide an additional US$2.50 per animal.[22] Phase feeding swine improves nutrient utilization and produces leaner carcasses, but these improvements depend on accurate weight predictions and the ability to deliver proper feed rations to animals of different sizes. Methods that attempt to reduce group weight variation, for example, housing pigs in large groups as in this study, may result in a significantly higher return per pig marketed.

Implications

- Under the conditions of this study, there was no difference in ADG or ADFI for nursery pigs housed in groups of 71 to 96 that had been commingled at 1 week of age in the farrowing room, compared to groups weaned at the same age from farrowing crates and sorted into pens of ten to 17 animals.
- There was a tendency for better FC in the group-housed nursery pigs: however, group-housed pigs were lighter than penned pigs of the same age entering this test.
- No differences in ADG during finishing were noted between groups of 21 to 26 pen-housed pigs and the previously commingled groups of 71 to 96 group-housed pigs.
- Skew in group weights was apparent in several groups of pen-housed pigs, but not in group-housed pigs.

References - refereed

1. McGlone JJ, Newby BE. Space requirements for finishing pigs in confinement: behavior and performance while group size and space vary. *Appl Anim Behav Sci*. 1994;39:331–338.

2. Chapple RP. Effect of stocking arrangement on pig performance. In: Batterham ES, ed. *Manipulating pig production IV*. Attwood, Victoria: Australasian Pig Science Association. 1993; 87–97.

3. Randolph JH, Cromwell GL, Stahly TS, Kratzer DD. Effects of group size and space allowance on performance and behavior of swine. *J Anim Sci*. 1981;53:922–927.

4. Heitman HJr, Hahn G, Kelly CF, Bond TE. Space allotment and performance of growing-finishing swine raised in confinement. *J Anim Sci.* 1961;20:543–546.

5. Lindvall RN. Effect of flooring material and number of pigs per pen on nursery pig performance. *J Anim Sci.* 1981;53:863–868.

6. Kornegay ET, Tinsley SE, Bryant KL. Evaluation of rearing systems and feed flavors for pigs weaned at two to three weeks of age. *J Anim Sci.* 1979; 48:999–1007.

7. McConnell JC, Eargle JC, Waldorf RC. Effects of weaning weight, co-mingling, group size and room temperature on pig performance. *J Anim Sci.* 1987; 65:1201–1206.

8. Petherick JC, Beattie AW, Bodero DAV. The effect of group size on the performance of growing pigs. *Anim Prod.* 1989;49:497–502.

9. Wolter BF, Ellis M, Curtis SE, Parr EN, Webel DM. Feeder location did not affect performance of weanling pigs in large groups. *J Anim Sci*. 2000;78:2784–2789.

10. Wolter BF, Ellis M, Curtis SE, Augspurger NR, Hamilton DN, Parr EN, Webel DM. Effect of group size on pig performance in a wean-to-finish production system. *J Anim Sci*. 2001;79:1067–1073.

11. McGlone, JJ, Stansbury WF, Tribble LF. Effects of heat and social stressors and within-pen weight variation on young pig performance and agonistic behavior. *J Anim Sci*. 1987;65: 456–462.

16. D'Agostino RB, Belanger A, D'Agostino RB Jr. A suggestion for using powerful and informative tests of normality. *Amer Stat*. 1990;44:316–321.

17. MidWest Plan Service. Swine Housing and Equipment Handbook, MWPS-8. 4th ed. Ames Iowa: MWPS; 1983:3–4.

18. Hawton J, Bache D, McKenzie B. High moisture grain for swine, In: Caldwell BJ, Newland HW, Hodson HH, eds. *Pork Industry Handbook*. W Lafayette, Indiana: Purdue University Cooperative Extension Service. 1980:PIH-73.

19. Gehlbach GD, Becker DE, Cox JL, Harmon BH, Jensen AH. Effect of floor space allowance and number per group on performance of growing-finishing swine. *J Anim Sci*. 1966;25:386.

20. Hyun Y. Considerations in the nutritional and environmental factors affecting feed intake and feed intake pattern in growing and finishing pigs [PhD dissertation]. University of Illinois, Urbana; 1997.

21. Spoolder HAM, Edwards SA, Corning S. Effects of group size and feeder space allowance on welfare in finished pigs. *Ani Sci.* 1999; 69:481–489.

References - non refereed

12. Verdoes N, Vermeer HM, Van Zeeland AJAM. American Society Agricultural Engineers, St Joseph, Michigan; 1988; ASAE paper #98–4070.

13. Korthals RL. *A review of open housed farrowing and experiences with electronic farrowing*. American Society Agricultural Engineers, St Joseph, Michigan; 1999; ASAE paper #99–4102.

14. Korthals RL. Comparison of electronic sow feeding and crated management of sows with different genetics. *Proc Intl Livestock Env Symp VI*; 2001:211–218.

15. Kornegay ET, Notter DR. Effect of floor space and number of pigs per pen on performance. *Pig News Info*. 1984; 5:23–33.

22. Ahlschwede WT, Vogel JA, Jones DD. Frequency of scale use in sorting market hogs [abstract]. *J Anim Sci.* 1993;71(Suppl 1):251.