Effect of space allowance during rearing and selection criteria on performance of gilts over three parities in a commercial swine production system[1,2]

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ABSTRACT: A total of 1,257 gilts were used to determine the effect of space allowance during rearing and age at puberty on total pigs produced and removal rate over 3 parities. There were 2 treatments. In treatment 1, gilts were given a space allowance of 1.13 m^2/gilt (15 gilts per pen), and in treatment 2, gilts were given 0.77 m^2/gilt (22 gilts per pen). Gilts (38 kg and 75 d of age) were individually weighed upon entry and before leaving the rearing site. They were scanned for backfat thickness and loin depth and had their feet and legs scored for structure, movement, and toe evenness before leaving the rearing site. Commencing at approximately 140 d of age, gilts were exposed to a vasectomized boar once daily with age of puberty recorded for all gilts attaining puberty before leaving the rearing site. Gilts were then moved to a specialized gilt breeding farm. When confirmed pregnant, they were moved to 1 of 9 sow farms at random, where gilts remained until removal from that herd. Space allowance in rearing had no effect ($P > 0.29$) on growth rate in rearing, backfat thickness and loin depth, total pigs produced, or removal rate. A greater percentage of gilts attained puberty ($P = 0.02$) and attained puberty at a younger age ($P < 0.01$) when given the greater space allowance in rearing. Gilts given the lower space allowance in rearing had more ($P = 0.04$) cracks on their rear hooves. Gilts attaining puberty at a younger age (<185 d) had a greater growth rate in rearing, greater backfat thickness at 200 d of age, and produced more ($P < 0.05$) pigs over parities 1 to 3. Gilts in the fastest growth-rate group in rearing (>860 g/d) had greater ($P < 0.05$) total born in parity 1, but total pigs produced to the end of parity 3 was not different ($P = 0.47$). Contrary to expectation, a fast growth rate in rearing did not negatively affect removal rate. Gilts served between 240 to 260 d of age produced more ($P < 0.01$) pigs by the end of parity 3 than those served at >260 d of age, whereas a greater ($P < 0.01$) percentage of gilts served at >280 d of age were removed by the end of parity 3. In conclusion, space allowance in rearing did not affect total pigs produced or removal rate; however, gilts that attained puberty at a younger age produced more pigs over parities 1 to 3.

Key words: gilt, puberty, space allowance

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INTRODUCTION

Annual replacement rates in commercial sow herds are commonly between 42 and 59%, which usually relates to a mean productive life span of 1.8 to 2.4 yr (MLC, 1999; PigChamp, 2005; Koketsu, 2007). From a review of the published data for the causes of culling in commercial sow herds (Hughes and Smits, 2002) reproductive problems were the main reasons for culling followed by locomotor problems, accounting for 10 and 14% of removals, respectively. Trauma is by far the most common cause of lameness in gilts and dry sows. Trauma leading to osteochondrosis can occur as

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early as 3 wk of age (Jorgensen and Sorensen, 1998). Early studies (Kuhlers et al., 1985; Rahe et al., 1987) suggest that stocking density or social crowding during the growing-finishing period may affect subsequent reproductive and maternal performance of gilts. Low stocking density during gestation increased ADG and BW of sows, whereas high stocking density increased skin lesions (Salak-Johnson et al., 2007).

Intuitively, gilts that attain puberty at a younger age should be more fertile and produce more pigs in their lifetime than gilts attaining puberty at an older age. However, there is only a small amount of scientific information available to support this hypothesis (Nelson et al., 1990; Holder et al., 1995). These early responders can be served (after second estrus) at a younger age and smaller mature physical size than the later responders. Thus, they may have lesser nutrient maintenance requirements throughout their lifetime and accumulate fewer nonproductive days (Brooks and Smith, 1980). We also would expect fewer leg and feet problems due to the smaller mature physical size (Foxcroft and Aherne, 2001). There were 2 main objectives of this experiment. The first was to compare performance over 3 parities of gilts given different space allowance during rearing following selection at 38 kg. The second was to determine the influence of age at puberty on total pigs produced over 3 parities.

MATERIALS AND METHODS

All animal care and handling procedures followed the farms' written guidelines in accordance with guidelines set forth by FASS (1999).

Animals and Facilities

The experiment was conducted in a commercial swine production facility in east central Minnesota. A total of 1,257 gilts were started on test at the initiation of the experiment. Gilts used in the experiment were a result of a Cambrough 42 × terminal line dam bred to a Landrace or Large White boar (PIC USA, Franklin, KY). Average age and BW of the gilts at the initiation of the experiment was 75 d and 38 kg, respectively. Gilts were housed in 4 similar barns during the rearing period. The barns were double-curtain-sided and operated on natural ventilation during the summer and mechanical ventilation during the winter with deep pit manure storage. Each barn was divided into 20 pens, which were 5.0 m long × 3.4 m wide. The barn had a totally slatted floor with a slat width of 17.8 cm and a slot opening of 2.5 cm. Each pen was equipped with a 4-hole dry self-feeder (Hog Slat Inc., Newton Grove, NC) and 1 cup waterer (Lou Manufacturing, Rosecreek, MN). Within each barn, there were 3 nontest pens: the first 2 pens on the left side of the barn and the first pen on the right side entering each barn. Each treatment was equally represented in each of the 4 barns. The first pen on the left side entering each barn was subdivided into 3 smaller pens. Two of the smaller pens were used to house the 2 vasectomized boars per barn, with 1 in each pen. Major reasons for removal in the rearing site were for lameness, respiratory problems, ulcers, and sudden deaths.

Diets, Treatments, and Measurements

All gilts were fed corn-soybean meal-based diets for the duration of the rearing period (Table 1). There were 2 space allowance treatments. Treatment 1 included gilts that were given a space allowance of 1.13 m^2/gilt (15 gilts/pen), whereas in treatment 2, gilts were given a space allowance of 0.77 m^2/gilt (22 gilts/pen). Before the arrival of the gilts to the site, pens within each barn were randomly allotted to treatments. On entry to the gilt development site, all gilts were individually tagged and weighed. Pens within each barn were filled at random as the gilts came off the truck on arrival, with each test pen being filled with the specified number of gilts set out in the allotment.

At 165 d of age, gilts were selected (production system selection; based on feet and legs and underline) and tagged with their sow identification number, and received 3 vaccinations: mycoplasma (Schering M + Pac, Intervet/Schering Plough Animal Health, Millsboro, DE), ileitis (Bl Enterisol Ileitis, Boehringer Ingelheim, Ridgefield, CT), and Farrowsure (Lepto/Parvo/Erysipelas combination, Pfizer Animal Health, New York, NY). Nonselected pigs were determined as those gilts that had poor feet and leg structure, poor ability to walk, and poor underlines (fewer than 12 teats, or one or more inverted teats). Approximately 1 to 2 wk before leaving the gilt-rearing site, backfat and loin depth were measured (SSD 500 V, Aloka, Wallingford, CT) and gilts were weighed and leg scored. Backfat and loin depth was measured at the 10th rib by a scanner certified by the National Swine Improvement Federation (NSIF, 2002). Front and rear legs of gilts were scored for structure, ability to walk (locomotor), and toe evenness (modified procedure of NSIF). Structure and movement was scored on a scale of 1 to 5, with 1 being poor, 3 average, and 5 excellent. Toe evenness was scored on a scale of 1 to 3, with 1 representing 1 very small and 1 normal toe or 2 very small toes, and 3 representing 2 even toes.

Timing and Frequency of Boar Exposure

Boar exposure was initiated when gilts averaged 140 d of age and continued until gilts were weighed before leaving the rearing site at approximately 200 d of age. There were 2 vasectomized boars in each barn. Average age of the vasectomized boars at initiation of exposure was 7.5 mo. Boar exposure was provided once daily, following the same order of barns and pens within barn each day. In each barn, the first vasectomized boar was exposed to 5 pens of gilts, rested for 40 min, and then exposed to 4 pens of gilts, whereas the second vasecto-

Table 1. Diets fed during the rearing, gestation, and lactation periods (as fed)

	Phase and BW range (kg)					
	1[1]	2[1]	3[1]	4[2]		
Item	18 to 40	40 to 77	77 to 113	113+	Gestation[2]	Lactation[2]
Ingredient, %						
Corn	73.71	69.97	78.95	71.87	80.90	56.65
Soybean meal	22.85	22.25	13.20	13.45	14.55	34.85
Choice white grease	—	—	—	1.00	1.00	5.00
Dicalcium P, 18.5% P	1.99	1.23	1.30	1.83	1.90	1.85
Limestone	0.70	0.80	0.80	0.80	0.75	0.75
Salt	0.35	0.35	0.35	0.50	0.50	0.50
Vitamins and minerals	0.25	0.25	0.25	0.30	0.30	0.30
Wheat middlings	—	5.00	5.00	10.00	—	—
Lysine-HCl	0.15	0.15	0.15	0.15	—	—
Choline chloride	—	—	—	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated						
Lysine, %	1.00	1.00	0.75	0.65	0.65	1.20
ME, Mcal/kg	3.29	3.29	3.31	3.31	3.33	3.51
Protein, %	16.9	17.1	13.6	14.0	13.6	21.0
Ca, %	0.78	0.66	0.65	0.77	0.76	0.81
P, %	0.73	0.62	0.60	0.73	0.69	0.76
Available P, %	0.43	0.31	0.31	0.43	0.42	0.43

[1]Provided (per kilogram of complete diet): 10,012 IU of vitamin A; 1,502 IU of vitamin D_3; 40 IU of vitamin E; 4.0 mg of vitamin K; 45.05 mg of niacin; 25.03 mg of pantothenic acid; 7.5 mg of riboflavin; 0.035 mg of B_{12}; 39.7 mg of Mn (oxide); 165.4 mg of Fe (sulfate); 165 mg of Zn (oxide); 16.5 mg of Cu (sulfate); 0.30 mg of I (as Ca iodate); and 0.30 mg of Se (as Na selenite).

[2]Provided (per kilogram of complete diet): 12,000 IU of vitamin A; 1,800 IU of vitamin D_3; 48 IU of vitamin E; 4.8 mg of vitamin K; 0.42 mg of vitamin B_{12}; 9.0 mg of riboflavin; 30.0 mg of pantothenic acid; 54 mg of niacin; 386 mg of choline, 0.22 mg of D-biotin; 1.65 mg of folic acid; 39.7 mg of Mn (oxide); 165.4 mg of Fe (sulfate); 165 mg of Zn (oxide); 16.5 mg of Cu (sulfate); 0.30 mg of I (as Ca iodate); and 0.30 mg of Se (as Na selenite).

mized boar was exposed to 4 pens of gilts, rested for 40 min, and then exposed to another 4 pens of gilts. The vasectomized boar used first each day was alternated from day to day, so each day a pen of gilts was exposed to a different vasectomized boar than the previous day. Vasectomized boars were placed into gilt pens and had full contact with gilts but were not permitted to breed gilts on test. Once weekly, the vasectomized boars were allowed to breed gilts in estrus in the off-test pens to increase their libido. The vasectomized boar was in the pen for 8 min for pens with 15 gilts/pen, and 12 min for pens with 22 gilts/pen. This provided all gilts a similar average amount of exposure time with the vasectomized boar. A sex odor aerosol (Intervet, Millsboro, DE) was sprayed on both flanks of the boar entering each pen to improve his stimulatory effect on gilts. While the boar was in a pen, gilts were tested by back pressure, and gilts in estrus were recorded (identification number and date). Puberty was determined as the first recorded estrus. The first gilts exhibited estrus approximately 8 d after initial boar exposure.

Gilt Breeding Farm and Sow Farms

At approximately 200 d of age, all gilts remaining on the experiment (n = 1,157) were moved to a specialized gilt breeding farm. At the gilt breeding farm, gilts were housed in groups of 17, irrespective of treatment in rearing, with a space allowance of 1.0 m^2/gilt, and allowed ad libitum access to feed. Each pen of gilts was provided a 5 to 10 min exposure to a vasectomized boar. Three weeks later, gilts were moved to the breeding barn where they were housed in stalls (2.13 m × 0.61 m). Each day, gilts were exposed to a vasectomized boar and, upon detection of estrus, were bred by AI. The estrus at which the gilts were bred was not known; however, based on random variation, one would expect that an equal proportion of gilts on each treatment were served at first, second, and third estrus. Before breeding, the gilts were fed ad libitum. After breeding, gilts were fed a maintenance level for 2 wk after breeding and then fed to condition for the remainder of gestation. All gilts were pregnancy checked at d 30 of gestation, and on confirmation of pregnancy on d 45, were moved to 1 of 9 sow farms. At the gilt breeding farm, gilts were fed the same diet before breeding and the same gestation diet after breeding.

At the sow farms, gilts were fed a standard corn-soybean meal gestation diet, formulated to contain 0.65% lysine and 3.33 Mcal of ME/kg (Table 1), with the feeding level based on body condition. The lactation diet was a corn-soybean meal–added fat diet, formulated to contain 1.2% lysine and 3.51 Mcal of ME/kg (Table 1), fed ad libitum. Date of service and farrowing, total pigs born, born alive, born dead, mummified, total pigs weaned, and weaning to estrus interval were recorded on all gilts that farrowed. Reason and date of removal from the experiment was recorded on all gilts that were removed before completing their third parity. Total weaned pig value (**US$**) was calculated as total pigs born alive over parities 1 to 3 – (total pigs born alive over parities 1 to 3 × average preweaning mortality parities 1 to 3, %) × $27 (the standard weaned pig value at the time of the study; USDA, 2007).

Statistical Analysis

Data were analyzed as a randomized complete block design using PROC MIXED (SAS Inst. Inc., Cary, NC). Pen was the experimental unit of analysis and pens were blocked by barn. Treatment (n = 2) was the main effect tested. The model included the fixed effect of treatment, and random effects were barn, treatment × barn interaction, and farm (i.e., the farm to which the gilts went after breeding). Because different numbers of gilts went to different farms, the model testing farm × treatment interaction did not converge. Additionally, effects of puberty (n = 2; attaining puberty at less than or greater than 185 d of age), ADG (n = 4; <680, 680 to 770, 770 to 860, and >860 g/d in rearing), and age at service (n = 4; <240, 240 to 260, 260 to 280, and >280 d of age) on sow performance were evaluated.

Sensory data analysis and chi square tests were used to test for differences in the proportion of gilts attaining puberty and age of puberty attainment (categorized as noted above). Loglinear models were used to test for effects of treatments, puberty group, ADG group, and service group on percentage of gilts farrowing 1, 2, and 3 litters, percentage of gilts removed by the end of parity 1, 2, and 3, and on removal reasons. Least squares means and SEM were reported.

Least squares means, protected by significant F-tests, were compared using *t*-tests. An α of $P < 0.05$ was considered significant and $P < 0.06 < P < 0.10$ was a tendency. Gilts removed before producing 1, 2, or 3 litters were considered as missing values for calculating individual parity data. Gilts that were culled before completing 3 parities were considered to have produced zero pigs in each parity not completed for calculation of total pigs born, born alive, and net weaned over parities 1 to 3.

RESULTS

Space Allowance in Rearing

Sixteen percent of gilts that started the experiment were removed before entering a sow farm, with approximately 7.5% removed during rearing and 8.5% removed at the breeding farm (Table 2). Percentage of gilts removed at either location was not affected ($P >$ 0.29) by space allowance during rearing. Space allowance in rearing had no effect ($P = 0.25$) on growth rate in rearing, backfat depth, or LM area at approximately 200 d of age. A greater proportion ($P = 0.02$) of gilts given the greater space allowance in rearing (37.2%) attained puberty compared with those given the lower space allowance (30.3%). Gilts given greater space allowance also attained puberty at a younger age ($P <$ 0.01) compared with those given less space allocation. Leg structure, ability to walk (locomotor properties), and toe evenness on the front and rear legs were not affected ($P > 0.23$) by space allowance in rearing (data not shown). A greater ($P = 0.04$) percentage of gilts given the greater space allowance in rearing had at least 1 crack on their rear hooves (14.5 vs. 6.6%, respectively) and tended ($P = 0.10$) to have a greater percentage of total cracks (front and rear hooves, 31.7 vs. 23.7%, respectively) compared with those given the lower space allowance during rearing.

On average, 95.6, 73.4, and 55.8% of gilts that went to sow farms farrowed 1, 2, and 3 litters, respectively, with no difference ($P > 0.30$) between the 2 treatment groups. Total pigs born, pigs born alive, pigs born dead, mummies, preweaning mortality, and weaning to estrus interval in parities 1, 2, and 3 were not affected ($P > 0.14$) by space allowance in rearing (Table 3). Pigs weaned in parity 3 tended ($P = 0.07$) to be greater for gilts given the greater space allowance in rearing. Total pigs born, born alive, and net weaned cumulative over parities 2 to 3 were not different ($P > 0.21$) for gilts given the 2 space allowances in rearing. Total nonreproductive days and age at removal were not influenced (P > 0.35) by space allowance. Space allowance in rearing did not affect ($P > 0.28$) percentage of gilts removed from sow farms by the end of parities 1, 2, or 3, with approximately 26.4, 39.6, and 46.8% of gilts removed at the 3 times, respectively. Reproductive problems accounted for the greatest proportion of gilts removed at 18.3%; this was followed by lameness at 9.4%.

Age of Puberty Attainment

Pubertal gilts (n = 1,110) were divided into 2 groups: puberty <185 d of age and >185 d of age (Table 4). The cut-off point was set at 185 d of age because this would result in at least a second estrus by 210 d of age, the target breeding age of this farm. Gilts attaining puberty at the younger age (<185 d) had greater ($P <$ 0.01) growth rate during rearing and thus tended to be heavier ($P = 0.06$) and had greater backfat thickness ($P < 0.01$) at approximately 200 d of age compared with those attaining puberty >185 d of age. Fewer (P < 0.05) gilts in the older puberty group farrowed 3 litters (64.2 vs. 53.6%). Total born in parity 1 tended (P = 0.10) to be greater for gilts in the younger compared with the older puberty group (Table 4). Born alive, born dead, mummies, pigs weaned, preweaning mortality, and weaning to estrus interval in parity 1 was not affected ($P > 0.13$) by puberty group. Farrowing performance in parities 2 and 3 was not affected ($P > 0.14$) by puberty group. Total pigs born, born alive, and net weaned cumulative over parities 1 to 3 were greater (P = 0.03) for gilts in the younger puberty group compared

Table 2. Effect of space allowance in rearing on removals before entering sow farms and performance during the rearing period

	Space allowance, m²/gilt			
Item	1.13	0.77	SE	$P \leq$
No. of gilts started on test	510	747	—	—
Gilts removed during rearing,[1,2] %	7.6 ± 1.44	7.5 ± 1.00	—	0.94
No. of gilts entering breeding farm	469	688	—	—
Gilts removed at breeding farm,[2,3] %	9.6 ± 1.88	7.4 ± 0.83	—	0.29
Entered sow farms	422	634	—	—
BW, kg				
Initial	38.0	38.0	0.46	0.93
Final	128.1	127.3	1.09	0.54
BW gain (0 to 120 d), g/d	758	752	10.0	0.49
Backfat, mm	18.2	17.7	0.38	0.28
Loin eye area, cm²	40.6	40.0	0.46	0.25
No. of gilts attaining puberty	182	216	—	—
Percentage of gilts attaining puberty,[4] %	37.2	30.3	—	0.02
Age at puberty,[4] d	182 ± 1.1	184 ± 0.8	—	0.01

[1]Removal reasons included 33.3% nonselected gilts, 10.4% lameness, 11.2% respiratory, 20.3% ulcers, and 24.8% other.

[2]Least squares means ± SEM.

[3]Removal reasons included 46.4% no estrus, 22% multiple rebreed, 8.8% lameness, 5.1% downer, and 17.7% other.

[4]Gilts that attained puberty before leaving the rearing site at approximately 200 d of age.

with those in the older group (Table 4). Total weaned pig value was greater for those in the younger puberty group compared with those in the older puberty group. Total nonproductive days or age at removal was not affected ($P > 0.21$) by age at puberty. A greater ($P < 0.01$) percentage of the gilts attaining puberty at the younger age were removed in rearing, with a tendency ($P = 0.07$) for more to be removed for physical injuries and as nonselects. A greater proportion ($P < 0.05$) of gilts in the older puberty group was removed by the end of parities 2 and 3. A greater proportion ($P < 0.05$) of gilts in the older puberty group was removed for farrowing problems compared with those in the younger puberty group.

Growth Rate Group in Rearing

With increasing growth rate group (<680, 680 to 770, 770 to 860, and >860), growth rate in rearing and weight at 200 d increased ($P < 0.01$: Table 5). Backfat thickness and LM area increased ($P < 0.01$) with increasing growth rate; however, loin eye area was similar among the 2 highest growth rate groups. There were no differences ($P > 0.15$) among growth rate groups in the percentage of sows farrowing 1, 2, and 3 litters. In parity 1, total born, born alive, and born dead were greater ($P < 0.05$) for gilts in the highest compared with those in the other growth rate groups. Number of mummies, pigs weaned, preweaning mortality, and weaning to estrus interval were not affected ($P > 0.17$) by growth rate group. In parity 2 preweaning mortality was greater ($P = 0.05$) for gilts in the second lowest growth rate group compared with those in the lowest and the second highest growth rate groups, but other farrowing performance data were not affected ($P > 31$) by growth rate group in rearing. In parity 3, gilts in the lowest growth rate group tended ($P = 0.08$) to have more pigs weaned. Total born, born alive, and net weaned cumulative over parities 1 to 3 were not different ($P > 0.39$) between growth rate groups. Total weaned pig value, nonreproductive days, and age at removal were not affected ($P < 0.59$) by growth rate during rearing. There was a tendency ($P = 0.06$) for more gilts in the lowest growth rate group to be removed in rearing. However, growth rate group in rearing had no effect ($P > 0.15$) on the percentage of gilts that went to sow farms removed from the experiment at the end of 3 parities.

Age at Service

Age at service group did not affect ($P > 0.59$) growth rate in rearing, or BW, backfat thickness, and loin eye area at 200 d of age. In parity 1, total born and born alive were greater ($P < 0.05$) for gilts served in the 240 to 260 d group, and the number of pigs weaned was less ($P < 0.05$) for gilts in the youngest and oldest service age groups (Table 6). In addition, weaning to estrus interval was longer ($P < 0.01$) for those gilts in the oldest service group. In parity 2, pigs weaned was less ($P < 0.01$) for gilts in the oldest service group compared with those served between 240 and 280 d of age and tended ($P = 0.10$) to be greater than for those in the youngest service group. In addition, gilts in the oldest service group had greater ($P < 0.01$) preweaning mortality and had a longer weaning to estrus interval compared with gilts in the younger service groups. In parity 3, born alive was greater ($P = 0.03$) and born dead tended (P

Table 3. Effect of space allowance during rearing on performance of gilts over 3 parities

	Space allowance, m²/gilt			
Item	1.13	0.77	SE	$P \leq$
No. of gilts	510	747	—	—
Age at first service, d	262	259	1.66	0.16
Parity 1				
Total born	11.3	11.3	0.21	0.89
Born alive	10.2	10.3	0.21	0.76
Born dead	0.73	0.71	0.09	0.85
Mummies	0.33	0.31	0.04	0.61
Pigs weaned	9.0	9.1	0.11	0.86
Preweaning mortality, %	10.4	9.6	0.74	0.36
Weaning to estrus interval, d	11.4	10.8	0.96	0.58
Parity 2				
Total born	10.9	10.8	0.26	0.79
Born alive	9.9	9.9	0.25	0.75
Born dead	0.76	0.69	0.10	0.53
Mummies	0.23	0.15	0.05	0.14
Pigs weaned	8.9	9.2	0.15	0.17
Preweaning mortality, %	8.7	8.7	1.03	0.99
Weaning to estrus interval, d	6.5	7.0	0.58	0.40
Parity 3				
Total born	11.7	11.4	0.34	0.48
Born alive	10.2	10.2	0.30	0.99
Born dead	1.19	1.00	0.17	0.36
Mummies	0.26	0.20	0.09	0.48
Pigs weaned	9.2	9.0	0.14	0.07
Preweaning mortality, %	9.5	10.3	1.13	0.49
Weaning to estrus interval, d	6.7	6.0	0.62	0.25
Parities 1 to 3[1]				
Total born	25.7	24.7	0.77	0.21
Born alive	23.2	22.5	0.71	0.37
Net weaned	21.0	20.5	0.57	0.36
Total weaned pig value,[2] $	565.9	551.1	17.56	0.41
Total nonproductive days[3]	94.0	90.9	2.72	0.35
Age at removal, d	510	509	11.06	0.97
Gilts removed in rearing,[4] %	17.3 ± 2.02	15.1 ± 1.08	—	0.36
Removal reasons in rearing,[4] %				
Reproduction	6.9 ± 1.62	5.4 ± 0.61	—	0.39
Lameness	1.0 ± 0.40	0.9 ± 0.37	—	0.94
Physical injuries	2.2 ± 0.72	2.5 ± 0.69	—	0.70
Ulcer or unthrifty	2.4 ± 0.61	1.6 ± 0.42	—	0.32
Nonselected gilts	2.7 ± 0.79	2.4 ± 0.58	—	0.74
Other[5]	2.1 ± 0.61	2.3 ± 0.47	—	0.88
Gilts died in rearing,[4] %	1.2 ± 0.44	0.8 ± 0.30	—	0.49
Gilts that went to sow farms and were removed by the end, %				
Parity 1	25.0 ± 1.83	27.4 ± 1.79	—	0.36
Parity 2	38.8 ± 2.16	40.2 ± 2.20	—	0.66
Parity 3	44.6 ± 2.34	48.2 ± 2.33	—	0.28
Gilts that went to sow farms and died by the end of parity 3,[4] %	9.7 ± 1.49	9.5 ± 1.12	—	0.91
Removal reasons sow farms,[4] %				
Reproduction	16.7 ± 1.72	19.3 ± 1.90	—	0.30
Lameness	8.7 ± 1.61	9.9 ± 1.14	—	0.52
Physical injuries	4.7 ± 1.21	2.3 ± 0.55	—	0.04
Farrowing problems	5.2 ± 1.21	4.8 ± 0.76	—	0.80
Ulcer or unthrifty	3.0 ± 0.70	3.5 ± 0.73	—	0.59
Other[5]	5.1 ± 0.94	6.9 ± 1.05	—	0.21

[1]Farrow performance data for gilts farrowing 1, 2, and(or) 3 litters.
[2]Total born alive – (total born alive × average preweaning mortality parities 1 to 3, %) × $27/pig.
[3]Days not pregnant or lactating from 200 d of age to breeding for fourth parity or prior removal.
[4]Least squares means ± SEM.
[5]Removal reasons include prolapse, respiratory problems, sudden deaths, and heat stress.

= 0.06) to be less for gilts in the oldest service group, whereas gilts in the youngest service group weaned (P < 0.01) fewer pigs.

Cumulative total born, born alive, and net weaned over the 3 parities was greater ($P < 0.05$) for gilts served between 240 to 260 d of age compared with those in

Table 4. Effect of age of puberty attainment on performance of gilts over 3 parities

Item	Age at puberty, d		SE	$P \leq$
	<185	≥185		
No. of gilts	165	945	—	—
BW at 200 d of age, kg	131.4	128.4	1.19	0.06
Growth rate in rearing, g/d	784	760	8.48	0.01
Backfat at 200 d of age, mm	20.6	17.8	0.42	0.01
Age at first service, d	258	261	2.50	0.16
Parity 1				
Total born	11.7	11.2	0.29	0.10
Born alive	10.7	10.2	0.28	0.13
Born dead	0.77	0.71	0.11	0.62
Mummies	0.31	0.32	0.05	0.96
Pigs weaned	9.2	9.0	0.16	0.26
Preweaning mortality, %	11.0	9.8	1.10	0.27
Weaning to estrus interval, d	10.6	11.1	1.35	0.69
Parity 2				
Total born	10.8	10.8	0.37	0.96
Born alive	9.9	9.9	0.35	0.90
Born dead	0.77	0.71	0.13	0.65
Mummies	0.19	0.18	0.07	0.91
Pigs weaned	9.2	9.1	0.19	0.63
Preweaning mortality, %	8.0	8.8	1.40	0.59
Weaning to estrus interval, d	6.7	6.8	0.80	0.87
Parity 3				
Total born	11.8	11.5	0.43	0.55
Born alive	10.7	10.2	0.38	0.20
Born dead	0.80	1.10	0.21	0.14
Mummies	0.28	0.21	0.12	0.60
Pigs weaned	9.2	9.1	0.18	0.56
Preweaning mortality, %	9.6	10.0	1.43	0.76
Weaning to estrus interval, d	5.4	6.5	0.76	0.14
Parities 1 to 3[1]				
Total born	27.3	24.8	1.09	0.03
Born alive	24.8	22.5	1.00	0.03
Net weaned	22.3	20.4	0.82	0.03
Total weaned pig value,[2] $	602.7	547.1	25.0	0.03
Total nonproductive days[3]	88	93	3.95	0.21
Age at removal, d	513	509	17.0	0.84
Gilts removed in rearing,[4] %	12.7 ± 2.98	3.5 ± 0.65	—	0.01
Removal reasons in rearing,[4] %				
Reproduction	5.5 ± 1.79	2.6 ± 0.58	—	0.13
Lameness	0.0 ± 0.00	0.0 ± 0.00	—	—
Physical injuries	3.0 ± 1.50	0.1 ± 0.11	—	0.07
Ulcer or unthrifty	0.6 ± 0.60	0.1 ± 0.11	—	0.42
Nonselected gilts	1.8 ± 1.04	0.4 ± 0.21	—	0.08
Other[5]	1.8 ± 1.02	0.2 ± 0.15	—	0.13
Gilts died in rearing,[4] %	0.0 ± 0.00	0.0 ± 0.00	—	—
Gilts that went to sow farms and were removed by the end,[4] %				
Parity 1	21.9 ± 2.93	26.9 ± 1.48	—	0.12
Parity 2	32.2 ± 3.73	40.7 ± 1.73	—	0.05
Parity 3	38.3 ± 3.85	47.5 ± 1.81	—	0.04
Gilts that went to sow farms and died by the end of parity 3,[4] %	8.1 ± 2.00	9.7 ± 1.07	—	0.47
Removal reasons sow farms,[4] %				
Reproduction	15.6 ± 3.31	18.4 ± 1.30	—	0.44
Lameness	6.6 ± 2.17	9.8 ± 1.14	—	0.18
Physical injuries	2.2 ± 1.18	3.4 ± 0.74	—	0.34
Farrowing problems	2.1 ± 1.20	5.5 ± 0.81	—	0.03
Ulcer or unthrifty	3.6 ± 1.18	3.2 ± 0.61	—	0.78
Other[5]	6.7 ± 2.06	5.6 ± 0.75	—	0.61

[1]Farrow performance data for gilts farrowing 1, 2, and(or) 3 litters.

[2]Total born alive – (total born alive × average preweaning mortality parities 1 to 3, %) × $27/pig.

[3]Days not pregnant or lactating from 200 d of age to breeding for fourth parity or prior removal.

[4]Least squares means ± SEM.

[5]Removal reasons include prolapse, respiratory problems, sudden deaths, and heat stress.

Table 5. Effect of growth rate during rearing (38 to 127 kg) on performance of gilts over 3 parities

	ADG group in rearing, g/d					
Item	<680	680–770	770–860	>860	SE	$P \leq$
No. of gilts	186	407	422	146	—	—
Growth rate in rearing, g/d	630[a]	725[b]	809[c]	901[d]	3.23	0.01
BW at 200 d of age, kg	112.3[a]	123.7[b]	134.5[c]	147.1[d]	0.68	0.01
Backfat depth at 200 d of age, mm	15.3[a]	17.2[b]	19.1[c]	21.3[d]	0.41	0.01
Loin eye area, cm^2	37.9[a]	40.0[b]	41.3[c]	42.1[c]	0.44	0.01
Age at first service, d	261	261	260	261	2.68	0.94
Parity 1						
Total born	10.7[a]	11.2[a]	11.3[a]	12.2[b]	0.31	0.03
Born alive	9.8[a]	10.3[a]	10.2[a]	10.9[b]	0.41	0.04
Born dead	0.64[a]	0.64[a]	0.74[a]	0.96[b]	0.12	0.05
Mummies	0.32	0.29	0.34	0.30	0.06	0.79
Pigs weaned	9.1	9.1	9.1	8.9	0.18	0.74
Preweaning mortality, %	8.1	10.7	10.1	9.5	1.18	0.17
Weaning to estrus interval, d	9.3	10.8	12.1	11.1	1.48	0.25
Parity 2						
Total born	10.5	10.8	10.9	11.0	0.41	0.77
Born alive	9.7	9.9	10.0	10.0	0.39	0.87
Born dead	0.66	0.81	0.67	0.74	0.14	0.58
Mummies	0.12	0.22	0.17	0.19	0.08	0.67
Pigs weaned	9.3	9.0	9.1	8.9	0.21	0.31
Preweaning mortality, %	6.6[a]	10.4[b]	7.9[a]	8.9[ab]	1.54	0.05
Weaning to estrus interval, d	6.0	6.8	7.0	7.2	0.93	0.70
Parity 3						
Total born	11.0	11.7	11.6	11.6	0.50	0.47
Born alive	10.1	10.2	10.3	10.1	0.45	0.92
Born dead	0.75	1.20	1.02	1.25	0.24	0.21
Mummies	0.11	0.30	0.19	0.23	0.14	0.50
Pigs weaned	9.5	9.0	9.1	8.9	0.20	0.08
Preweaning mortality, %	8.5	9.4	11.2	10.0	1.65	0.38
Weaning to estrus interval, d	5.6	6.5	6.5	5.6	0.90	0.53
Parities 1 to 3[1]						
Total born	23.6	25.6	25.0	25.4	1.19	0.39
Born alive	21.7	23.2	22.8	22.8	1.10	0.63
Net weaned	20.6	20.8	20.7	20.0	0.90	0.82
Total weaned pig value,[2] $	543.7	560.2	559.3	559.1	27.3	0.94
Total nonproductive days[3]	93	91	94	90	4.16	0.59
Age at removal, d	499	517	507	507	16.4	0.71
Gilts removed in rearing,[4] %	14.0 ± 2.54	8.4 ± 1.37	8.8 ± 1.38	5.5 ± 1.89	—	0.06
Removal reasons in rearing,[4] %						
Reproduction	9.1 ± 1.72	5.7 ± 1.11	6.6 ± 1.53	4.8 ± 1.70	—	0.30
Lameness	2.2 ± 1.06	0.7 ± 0.42	0.5 ± 0.33	0.0	—	0.12
Physical injuries	1.1 ± 0.76	0.5 ± 0.35	0.0 ± 0.00	0.0 ± 0.00	—	0.12
Ulcer or unthrifty	1.1 ± 0.75	0.0 ± 0.00	0.7 ± 0.41	0.0 ± 0.00	—	0.09
Nonselected gilts	0.5 ± 0.54	0.5 ± 0.35	0.0 ± 0.00	0.0 ± 0.00	—	0.26
Other[5]	0.0 ± 0.00	1.0 ± 0.49	1.0 ± 0.47	0.7 ± 0.68	—	0.36
Gilts died in rearing,[4] %	1.1 ± 0.76	0.5 ± 0.35	0.2 ± 0.24	0.0 ± 0.00	—	0.40
Gilts that went to sow farms and were removed by the end[4]						
Parity 1	26.4 ± 3.61	24.4 ± 2.24	27.0 ± 2.56	27.4 ± 3.79	—	0.84
Parity 2	42.7 ± 3.68	34.5 ± 2.57	40.4 ± 2.68	43.7 ± 4.23	—	0.15
Parity 3	48.8 ± 3.69	42.1 ± 2.78	46.5 ± 2.83	49.9 ± 4.06	—	0.32
Gilts that went to sow farms and died by the end of parity 3,[4] %	8.4 ± 2.24	8.5 ± 1.37	9.7 ± 1.69	13.9 ± 2.67	—	0.35
Removal reasons sow farms,[4] %						
Reproduction	20.3 ± 2.88	16.6 ± 2.13	18.3 ± 2.08	15.2 ± 2.79	—	0.60
Lameness	9.2 ± 2.12	7.2 ± 1.46	10.0 ± 1.69	11.2 ± 2.76	—	0.47
Physical injuries	2.6 ± 1.13	3.3 ± 0.98	2.9 ± 0.85	4.5 ± 1.74	—	0.81
Farrowing problems	5.2 ± 1.91	5.4 ± 1.19	4.3 ± 1.22	4.5 ± 1.76	—	0.92
Ulcer or unthrifty	3.0 ± 1.21	3.2 ± 1.10	3.3 ± 0.74	2.8 ± 1.20	—	0.99
Other[5]	6.8 ± 2.15	4.0 ± 1.08	6.1 ± 1.11	8.0 ± 2.09	—	0.29

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

[1]Farrow performance data for gilts farrowing 1, 2, and(or) 3 litters.

[2]Total born alive – (total born alive × average preweaning mortality parities 1 to 3, %) × $27/pig.

[3]Days not pregnant or lactating from 200 d of age to breeding for fourth parity or prior culling.

[4]Least squares means ± SEM.

[5]Removal reasons include prolapse, respiratory problems, sudden deaths, and heat stress.

the 2 older service groups but not different to those in the youngest group. Total nonreproductive days were greater ($P < 0.01$) with increased breeding age group. Age at removal was not affected ($P = 0.37$). A greater percentage of gilts ($P < 0.01$) in the oldest service group were removed by the end of parities 1, 2, and 3 compared with those served at <260 d of age. Fewer gilts ($P < 0.01$) bred between 240 and 260 d of age were removed for reproductive problems, and there was a tendency ($P = 0.09$) for fewer gilts bred at <240 d of age to be removed for lameness, whereas more ($P = 0.05$) gilts bred at <280 d of age were removed for physical injuries.

DISCUSSION

The environment in which a pig is reared, including factors such as floor space allowance and group size, may influence feed intake and growth rate in rearing (Edmonds et al., 1998; Hyun et al., 1998; Hamilton et

Table 6. Effect of age at service on performance of gilts over parities 1 to 3

	Age at service, d					
Item	<240	240–260	260–280	>280	SE	$P \leq$
No. of gilts	211	563	163	113	—	—
Age at first service, d	236[a]	248[b]	267[c]	316[d]	1.44	0.01
Parity 1						
Total born	11.1[a]	11.6[b]	10.9[a]	10.9[a]	0.34	0.02
Born alive	10.1	10.6	9.9	9.8	0.36	0.01
Born dead	0.68	0.70	0.71	0.84	0.12	0.64
Mummies	0.31	0.31	0.32	0.34	0.07	0.99
Pigs weaned	8.9[a]	9.2[b]	9.2[b]	8.7[a]	0.18	0.02
Preweaning mortality, %	10.4	9.4	9.2	11.8	1.27	0.25
Weaning to estrus interval, d	11.0[a]	10.2[a]	9.9[a]	16.1[b]	1.66	0.01
Parity 2						
Total born	10.8	10.8	10.8	11.0	0.47	0.99
Born alive	10.0	9.9	10.0	9.7	0.45	0.92
Born dead	0.72	0.71	0.60	0.98	0.15	0.27
Mummies	0.12	0.19	0.16	0.32	0.09	0.29
Pigs weaned	8.9[ac]	9.2[ab]	9.5[b]	8.5[c]	0.25	0.01
Preweaning mortality, %	8.0[a]	8.3[a]	6.0[a]	15.6[b]	1.80	0.01
Weaning to estrus interval, d	6.7[a]	6.2[a]	6.8[a]	11.0[b]	1.10	0.01
Parity 3						
Total born	11.7	11.5	11.3	12.8	0.66	0.31
Born alive	9.8[a]	10.2[a]	10.0[a]	12.0[b]	0.58	0.03
Born dead	1.47	0.98	1.14	0.71	0.30	0.06
Mummies	0.43	0.21	0.11	0.10	0.18	0.14
Pigs weaned	8.7[a]	9.2[bc]	8.9[ac]	9.4[bc]	0.27	0.01
Preweaning mortality, %	10.9	9.2	10.2	13.1	2.14	0.33
Weaning to estrus interval, d	6.5	6.1	6.8	6.5	1.12	0.85
Parity 1 and 3[1]						
Total born	25.8[ab]	27.4[a]	23.5[b]	18.6[c]	1.23	0.01
Born alive	23.2[ab]	25.1[a]	21.4[b]	16.8[c]	1.13	0.01
Net weaned	21.1[ab]	22.8[a]	19.8[b]	14.4[c]	0.92	0.01
Total weaned pig value,[2] $	568.1[a]	622.0[b]	532.5[a]	401.1[c]	28.2	0.01
Total nonreproductive days[3]	64[a]	76[b]	107[c]	153[d]	3.66	0.01
Age at removal, d	499	519	500	518	16.7	0.37
Gilts removed by the end,[4] %						
Parity 1	24.1 ± 3.05[a]	19.5 ± 1.54[a]	34.1 ± 3.77[b]	46.0 ± 5.11[b]	—	0.01
Parity 2	40.5 ± 3.94[a]	34.2 ± 2.22[a]	42.5 ± 3.96[ab]	53.8 ± 4.75[b]	—	0.01
Parity 3	44.8 ± 3.65[a]	41.5 ± 2.32[a]	49.8 ± 3.90[ab]	61.9 ± 4.90[b]	—	0.01
Gilts died by the end of parity 3,[4] %	7.3 ± 2.05	10.2 ± 1.26	10.5 ± 2.21	7.7 ± 2.49	—	0.51
Removal reasons,[4] %						
Reproduction	20.5 ± 3.12[a]	13.4 ± 1.46[b]	19.2 ± 2.87[a]	28.4 ± 4.02[a]	—	0.01
Lameness	5.6 ± 1.79	8.9 ± 1.18	10.2 ± 2.27	15.7 ± 3.44	—	0.09
Physical injuries	1.5 ± 0.91[a]	4.3 ± 1.00[a]	1.9 ± 0.99[a]	0.0 ± 0.0[b]	—	0.05
Farrowing problems	6.8 ± 1.61	4.1 ± 0.73	5.9 ± 2.06	5.0 ± 2.04	—	0.45
Ulcer or unthrifty	4.2 ± 1.33	2.6 ± 0.65	4.4 ± 1.52	3.0 ± 1.47	—	0.49
Other[5]	3.6 ± 1.40	6.5 ± 1.11	6.1 ± 1.90	5.6 ± 2.14	—	0.46

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

[1]Farrow performance data for gilts farrowing 1, 2 and(or) 3 litters.

[2]Total born alive – (total born alive × average preweaning mortality parities 1 to 3, %) × $27/pig.

[3]Days not pregnant or lactating from 200 d of age to breeding for fourth parity or prior removal.

[4]Least squares means ± SEM.

[5]Removal reasons include prolapse, respiratory, sudden deaths, and heat stress.

al., 2003). In the present experiment, space allowance and group size did not affect growth rate in rearing, which agrees with results reported by Kuhlers et al. (1985). Randolph et al. (1981) and McGlone and Newby (1994) reported no effect on growth in group sizes from 5 to 40 pigs. One item to consider in our study was that we changed group size to achieve the different floor space treatments. However, Christenson (1984) determined that the number of gilts per pen within the range used in this study would not affect estrous characteristics of gilts. Gonyou et al. (2006) suggested a space allowance of 0.035 m^2 per kg of $BW^{0.667}$ in rearing to optimize ADFI and ADG for growing-finishing pigs. Space allowance for treatments 1 and 2 equated to 104 and 153% of that recommended by Gonyou et al. (2006) based on a midpoint weight of 83 kg.

Space allowance did not affect structure, locomotor, and toe evenness scoring in this experiment. However, gilts housed at the greater space allowance during rearing had a greater percentage of cracks on their rear hooves. We hypothesize that the greater space allowance in rearing may have allowed more physical activity, leading to a greater probability of gilts catching their hooves in the slat openings, in turn resulting in a greater percentage of cracks. Percentage of gilts removed from the experiment during rearing and death rate was not affected by space allowance, which is in agreement with results of some experiments (Brumm et al., 2001; Wolter et al., 2002) but contrary to results reported by others (McGlone and Newby, 1994; Brumm and Miller, 1996; Hamilton et al., 2003).

Results from the current experiment suggest that a greater percentage of the gilts given the greater space allowance in rearing attained puberty before 200 d of age similar to the results of Rahe et al. (1987). This is the first experiment, to our knowledge, that investigated the effect of space allowance during rearing on both the number of pigs produced over multiple parities and removal reasons. In the current experiment, total pigs born and pigs born alive were not different between the 2 space allowances in rearing. This finding agrees with Brooks and Smith (1980). However, the lack of increase in litter size is in contrast to the results of Kuhlers et al. (1985) who reported that gilts reared at a lower stocking density per pen delivered larger litters at first farrowing. Our data suggest that the space restriction during rearing for the high stocking density group does not appear to be intrusive enough to affect litter size or removal rate during the first 3 parities as demonstrated in other experiments.

The total percentage of gilts removed and specifically for lameness was not affected by space allowance during rearing. The likelihood of a sow being culled for lameness is greater for young sows compared with older sows, particularly for gilts and parity 1 sows (D'Allaire et al., 1987; Dewey et al.; 1993; Lucia, 1997; Patterson et al., 1997). Others have reported (Dewey et al., 1992) that high density of pigs and slatted floors during the finishing period are associated with a greater risk of removal in sows. The lack of a difference in total pigs produced and removals may be attributable to the more generous space allowance given for the high stocking density treatment (104% of that recommended by Gonyou et al., 2006; to optimize ADG and ADFI in growing-finishing phases) than utilized in other experiments (0.77 vs. 0.25 to 0.56 m^2; Hyun et al., 1998; Hamilton et al., 2003).

Although all gilts received the same duration of exposure to vasectomized boars (32 s/gilt daily) from 140 to 200 d of age, a greater percentage of gilts given the greater space allowance during rearing attained puberty. Gilts given greater space allocation in rearing also attained puberty at a younger age. Thirty-four percent of gilts attained puberty within 60 d of initiation of boar exposure in the present experiment. Patterson et al. (2003) reported that 80% of gilts were pubertal within 40 d of boar exposure. Three potential reasons contributed to the poorer response in the present experiment. First, the vasectomized boars utilized were only 7.5 mo of age at initiation of boar exposure. Young boars were used in this production system because the farm was in the process of a repopulation of their system and older boars could not be brought into the system for biosecurity reasons. Previous experiments have shown that boars must be at least 10 mo of age before 16-androstene steroids are produced in appreciable amounts in the submaxillary salivary glands (Booth, 1975; Kirkwood and Hughes, 1981; Zimmerman and Kopf, 1986); 16-androstene steroids aid in the induction of puberty in prepubertal gilts. This age-related difference in boar stimulus value is due to the timing of hypertrophy of the serous cells within the submaxillary salivary glands of the boar (Hughes et al., 1990). Second, in the present experiment, gilts in both space allowance groups received 8 and 12 min/d exposure to a vasectomized boar; this is less than the recommended exposure time of 15 min daily/group of 12 to 15 gilts outlined by Levis (2000). Third, gilts were positive for enzootic pneumonia (*Mycoplasma hyopneumoniae*) when they entered the rearing site and showed clinical signs from 140 to 180 d of age. Previous research has suggested that once the health of an animal has been challenged, reproduction is compromised and is of less importance while the body fights the imminent disease challenge (Britt et al., 1999).

In the current experiment, gilts attaining puberty at a younger age (<185 d of age) had greater growth rate and backfat thickness in rearing compared with those attaining puberty at an older age similar to results reported by Beltranena et al. (1991). Similar to our results, Nelson et al. (1990) and Holder et al. (1995) observed that gilts attaining puberty at the younger age had greater total born, born alive, and net weaned over their first 3 parities, suggesting that the gilts attaining puberty at a younger age are more fertile (i.e., they will produce more pigs in their lifetime). The differences in total pigs born, pigs born alive, and pigs weaned were significantly different for overall parities 1 through 3 as a result of more sows in the <185 d to puberty group completing the entire 3 parities compared with those reaching puberty >185 d. In addition, total weaned pig value was greater for gilts in the younger puberty group ($603 vs. $547). Contrary to the data reported by Patterson et al. (2003), total number of nonproductive days was not different between gilts in the younger and older puberty groups. The older puberty group tended to be lighter and had less backfat at approximately 200 d of age, and age at service was not different between the 2 puberty groups. The greater proportion of gilts removed for farrowing problems in the older puberty group was unexpected and difficult to explain in the present experiment. The percentage of sows removed for farrowing problems was not affected by space allowance or growth rate in rearing.

Previous studies showed that gilts with excessively high growth rates in rearing are more likely to be prematurely culled for lameness and thus may have reduced lifetime productivity (Jongbloed et al., 1984; Sorenson et al., 1993; Gill and Taylor, 1999). This was not observed in our study. A large retrospective study in Sweden suggested that gilts that had a greater growth rate from birth to 100 kg of BW had larger litters (parities 1 to 5), shorter weaning to service interval (parities 1 to 5), and greater farrowing rates (parities 2 to 5) than gilts with a lower growth rate (Tummaruk et al., 2001). This finding agrees with our parity 1 data only. Gilts with the greatest growth rate had approximately 1 extra pig born and born alive in parity 1, but not in parity 2, 3, or overall. One could speculate that the greater reproductive performance reported by Tummaruk et al. (2001) for animals with the faster growth rate in rearing may be related to the greater weight and protein reserves these animals have at puberty and at first and successive breedings. The data of Clowes et al. (2003) support the suggestion of a protective effect of a larger body protein mass at first farrowing on subsequent reproductive performance. Contrary to previous suggestions (Jongbloed et al., 1984; Sorenson et al., 1993; Gill and Taylor, 1999), growth rate in rearing in the current experiment did not influence the percentage of gilts removed or removal reasons at the end of parities 1, 2, and 3. Our data are supported by Crenshaw (2003) who suggested that fast growth in rearing did not impair skeletal integrity in rapidly growing pigs compared with slower growing pigs.

Average total born and born alive in parity 1 did not increase with increasing age at service or farrowing contrary to many previous studies (Le Cozler et al., 1998; Koketsu et al., 1999; Tummaruk et al., 2001). Average age at service of 261 d in the present experiment is much greater than in many previous experiments, which may explain the lack of increase in total born and born alive with increasing age at service. Although estrus at breeding was not determined, based on random variation, one would expect that an equal number of gilts in each group were served at their first, second, and third estrus. Our results suggest that gilts that were >260 d at first mating had reduced lifetime performance, which is supported by increasing amounts of production data (Le Cozler et al., 1998; Koketsu et al., 1999; Tummaruk et al., 2001). A reduction in total pigs produced is mainly attributable to the greater removal rate, primarily for lameness and reproductive problems, of these gilts in the older age groups. A greater proportion of gilts served at >280 d of age were removed by the end of parities 1, 2, and 3 compared with those served at <260 d of age. As age at service increased, more gilts were removed for lameness, which was probably due to the greater mature physical size of these animals. Total weaned pig value was much greater for gilts served at <260 d compared with those served at >260 d of age ($127 per sow over 3 parities on average). In addition, total number of nonproductive days was greater for sows served at >260 d of age, resulting in increased feed and housing costs ($0.30 and $0.16 per d), and reduced opportunity margin due to reduced pigs produced per sow per year (22 pigs/sow yearly ÷ 365 × $27/weaned pig = $1.63/d), resulting in a lost margin of approximately $111 per sow over 3 parities.

Removal rate in the rearing period was relatively low at 16% and not affected by treatment, with 2.6% of these gilts considered as nonselected gilts (unsound or poor teat confirmation). In the present experiment, 19.9% of gilts were removed from the experiment before their first farrowing, which is very similar to the values reported by den Hartog and Noordewier (1984) and Lucia (1997). A total of 3.7% of gilts never showed signs of behavioral estrus and were culled. This number is within the range of values reported by Rozeboom et al. (1995) of 2.2% and Ehnvall et al. (1981) of 6%. Similar to the results of many other studies (Pedersen, 1996; Lucia, 1997; Patterson et al., 1997; Hughes and Smits, 2002), reproductive problems accounted for the greatest percentage of removals in our experiment at 18.3% of total removals. Removals for lameness (locomotor problems) accounted for 9.4% of all gilts, which again agrees with values reported in previous studies (Lucia, 1997; Patterson et al., 1997; Hughes and Smits, 2002), with ulcers, unthrifty, and farrowing problems accounting for the other major reasons for removal.

In conclusion, space allowance in rearing had no effect on growth rate in rearing, total pigs produced, and removal rate over the first 3 parities in gilts reared in a commercial swine production system. Fast growth rate in rearing did not negatively affect total pigs produced or culling rate. Gilts attaining puberty at a younger age (<185 d) produced more pigs over the first 3 parities. Therefore, if a swine production system is short on service-eligible gilts, those attaining puberty at >260 d of age can be served to produce 1 litter, but should be culled as soon as possible.

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