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Production Through Four Parities of Prolific Females Developed With and Without Energy Restriction

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Production Through Four Parities of Prolific Females Developed With and Without Energy Restriction

A 25% energy restriction during development delays sexual development of gilts but has no effect on the reproductive rate of those reaching sexual maturity.

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Summary

This experiment evaluated the effects of developing gilts with ad libitum access to feed to breeding age (226 days) or feed intake restriction from 123 to 226 days of age. Gilts were managed in groups of 10 per pen. Those in the restricted group were fed two meals per day so that energy intake was 75% of that of the ad libitum group. Protein, vitamins, and minerals in their diet were increased so that daily intake of these nutrients was not restricted. A total of 661 gilts of two genetic lines that differed in reproductive rate and in lean growth rate started the experiment at 60 days of age, and one-half of the gilts of each line were developed with each feeding regimen. Growth and backfat were recorded at 14-day intervals from 60 to 226 days of age. Boar exposure to determine age at puberty was initiated at 140 days of age. A total of 509 gilts that could be mated at second or later post-pubertal estrus were designated as breeders and their production through four parities was recorded. Females were managed alike after 230 days of age and were culled only for reproductive failure, death, ruptures, or severe foot and leg problems. No interactions of genetic line by treatment were significant as females of both lines responded similarly to the developmental regimens. Developing gilts with energy restriction significantly decreased the proportion of gilts that expressed a pubertal estrus by 230 days of age, from 96% to 86% and increased their age at puberty from 174.1 to 177.5 days. Thereafter, females developed with both regimens had similar reproductive performance. Measures of productivity through parity 4 were 8 to 11% greater for females developed with energy restriction, but none of the differences were significant ($P \geq 0.14$).

Introduction

In several species, restricting energy intake postweaning, without limiting other nutrients, often increases longevity. Sometimes, reallocation of resources occurs such that animals cannot combine high rates of fecundity with extended lifespans. However, this outcome does not always happen. In one study, mice restricted in energy intake postweaning lived longer without a reduction in reproductive rate (Johnston et al., 2006, Proc. R. Soc. B 273:1369-1374). Consistent with these results, a series of experiments at the USDA Meat Animal Research Center (Klindt et al, 1999, J. Anim. Sci. 77:1968-1976, 2001, 79:787-795, and 2001, 79:2513-2523) demonstrated that moderate feed restriction during prepubertal development of gilts may increase reproductive efficiency through first parity.

Today's commercial gilts are often managed to achieve weights of at least 136 kg (300 lb) before they are mated or inseminated, and it is generally believed that some minimum amount of backfat is needed for reproduction. Thus, gilts are often developed to breeding age with ad libitum access to feed. The experiments cited above indicate that this management strategy may be detrimental to long-term reproductive performance. Therefore, we designed an experiment to examine whether restricting energy intake during a gilt's developmental period will increase their longevity and lifetime productivity.

Because optimum gilt development regimens may vary among genetic lines, depending on the line's prolificacy and rate of lean growth, gilts of two lines that differed in fertility, litter size, and rate of lean growth were managed with ad libitum access to feed to breeding age or with 25% restriction of energy from 123 days of age to breeding. Reproduction through parity 4 was evaluated. The experiment was done in four replications with a total of 661 gilts. Reproductive performance of females through parity 4 for gilts of replications 1 to 3 are in the *2008 Nebraska Swine Report* (Miller et al., 2008; Johnson et al., 2008). A fourth replication was subsequently added to the project, and the *2009 Nebraska Swine Report* summarizes productivity of all females through parity 1. With completion of fourth parity litters by replication 4 females in summer 2009, the experiment is complete, and production of all females through 4 parities is summarized here.

Materials and Methods

Gilt Populations

Two populations of gilts were used. One was the Large White by Landrace crossbred female used in the UNL swine nutrition program. The project gilts

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were the progeny of Large White-Landrace cross sows that had been inseminated with semen of industry maternal line (L_M) boars and are designated as LW x LR cross. The other population, Line 45X, were progeny of UNL selection Line 45 sows that had been inseminated with semen of the same L_M boars used to produce LW x LR gilts. Line 45 has now undergone 29 generations of selection for increased litter size with additional selection for increased growth and decreased backfat in the last seven generations. The Line 45 dams used to produce gilts for the experiment were from generations 25, 26, and 27. Based on previous data, L45X gilts are expected to be more prolific than LW x LR gilts, but also have somewhat slower growth and greater backfat thickness.

Gilt Management and Dietary Regimens

Project gilts were born in batches during December 2004 and January 2005 (Rep 1), May 2005 (Rep 2), November 2005 (Rep 3), and May and June 2007 (Rep 4). A total of 661 gilts began the experiment (157 to 185 gilts per replication) at 60 days of age; 639 gilts completed the growth phase of the experiment that ended at 226 days of age.

Dams of project gilts were managed alike during the farrowing/lactation period. After weaning, all gilts were managed alike in the nursery until approximately 60 days of age (20.9 kg, 46 lb). They were then moved to the grow-finish facility where they were penned (10/pen) by line-treatment designation. They all were allowed ad libitum access to a corn-soybean meal-based diet and were managed alike until 123 days of age. A 3-phase growing-finishing diet was used: phase 1, 1.15% lysine (60 days to 36.3 kg, 80 lb); phase 2, 1.0% lysine (36.3 to 59 kg, 80 to 130 lb); and phase 3, 0.90% lysine (59 kg, 130 lb, to 123 days).

At 123 days, pens of gilts on the ad libitum regimen (AL) were allowed ad libitum access to a corn-soybean meal-based diet (0.70% lysine, 0.70% Ca, 0.60% P) until they were moved into the breeding barn. Gilts on the restricted intake regimen (R) received a corn-soybean meal-based diet at approximately 75% of the energy intake as AL-fed gilts until moved into the breeding barn. Energy restriction was achieved by predicting intake with a quadratic equation of average daily feed intake on body weight of AL-fed gilts. The predicted ad libitum intake (based on the projected body weight for the upcoming two-week period) was multiplied by 0.75 to determine the daily feed intake for R gilts. The diet contained 0.93% lysine, 1.0% Ca, and 0.80% P. All vitamins and minerals, except selenium, were increased so that daily intake of these nutrients per unit of body weight was expected to be equal for gilts on both diets. Additional details of the diets and management are in two articles in the *2007 Nebraska Swine Report* (Johnson et al, *2007 Nebraska Swine Report*; Miller et al., *2007 Nebraska Swine Report*).

Gilts were weighed and backfat and longissimus muscle area were recorded every 14 days until final measurements were recorded at an average age of 226 days. Beginning at approximately 140 days of age, gilts were moved by pen to an adjacent building where boar exposure and estrus detection occurred. Date of first observed estrus and each additional estrus were recorded.

Breeding and Lactation Management

Gilts in good health that could be mated at second or later postpubertal estrus during a predetermined breeding period were identified as breeders and moved to the breeding barn at approximately 230 days of age. Breeding commenced approximately 10 days later. A breeding period of 25 days (Rep 1), 24 days (Rep 2), 26 days (Rep 3), and 28 days (Rep 4) was used to match the unit's production schedule. Gilts were checked twice daily for estrus and inseminated each day that they were observed in estrus. Insemination was with semen from commercial terminal sire line boars. Gilts were in pens of approximately eight per pen until inseminated and then were moved to gestation stalls. Gilts that did not express estrus, those that were mated but diagnosed open with an ultrasound pregnancy test 50 days postbreeding, those that were diagnosed pregnant but did not farrow a litter, lame gilts, and gilts in poor health were culled.

While in the breeding barn and during gestation, all gilts were fed a standard corn-soybean meal-based diet (13.8% protein, 0.66% lysine) at the rate of 1.8 kg, 4.0 lb, daily until 90 days of gestation when feed intake was increased to 2.3 kg, 5.0 lb, daily. At approximately 110 days of gestation, females were weighed, scanned for 10th rib backfat thickness, and placed in farrowing crates in rooms of 12 crates per room. They were fed 2.7 kg, 6 lb, per day of a corn-soybean meal-based lactation diet (18.5% protein, 1.0% lysine). Sows were provided only a small amount of feed on the day they farrowed, 2.7 kg, 6 lb, on the second day, 4.5 kg, 10 lb, the third day, and then were given ad libitum access to feed. The total number and number of live pigs in each litter were recorded. Pigs were fostered among litters without regard to line or gilt developmental regimen to reduce variation in number nursed per sow. Litters were weaned at an average age of 17 days and the number weaned and total litter weight were recorded. Weight and ultrasonic backfat of each sow at weaning was recorded. They were then moved to the breeding area and placed in pens of approximately eight sows per pen.

Feeding, estrus detection, insemination, and management during gestation and subsequent lactations were as described above for gilts. The breeding period for sows within replications and parities ranged from 24 to 32 days. Breeding continued until 10 days after the last sow in the replication was weaned. Every sow had at least 10 days to express postweaning estrus, and most had 15 to 20 days. Sows that did not express estrus, those that were detected to be open by ultrasonic pregnancy test, and those diagnosed pregnant but that did not farrow a litter were culled. Lame and unhealthy sows also were culled.

Traits and Data Analysis

Reproductive success is an all or none outcome; gilts and sows either did or did not produce litters. This outcome is a binomial trait that can

Table 1. **Numbers of gilts from 60 to 230 days of age.**

		outcome, day 0 to final test date						Culled, not breeders				
Line[a]	Trt[b]	N_{60}	$N_{\text{Died, 60-123 days}}$	$N_{\text{123 days}}$	$N_{\text{died/FL/Rupt,123 to 226 days}}$[c]	$N_{\text{226 days}}$	N_{AP}[d]	$N_{\text{No AP}}$	$N_{\text{AP-late}}$[e]	$N_{\text{Died/FL/Rupt}}$[f]	N_{Random}[g]	No Breeders
LW x LR	A	177	1	176	2	174	159	15	3	6	11	139
LW x LR	R	178	3	175	4	171	133	38	4	2	4	123
L45X	A	153	3	150	3	147	143	4	3	1	10	129
L45X	R	153	2	151	4	147	133	14	5	2	8	118
Total		661	9	652	13	639	568	71	15	11	33	509

[a]LW x LR = Large White x Landrace cross females, L45X = Line 45 cross females.
[b]A = ad libitum access to feed to breeding age (230 days), R = energy restriction (75% of A) from 123 to 230 days of age.
[c]Number that died or were removed from test for foot and leg problems, or were ruptured.
[d]Number that expressed pubertal estrus.
[e]Number that expressed pubertal estrus late in the development period, but were culled because they could not be mated at second postpubertal estrus.
[f]Number completing development period that died, ruptured, or were culled for foot/leg problems.
[g]Number that were culled randomly to reduce numbers to available breeding/farrowing spaces.

Table 2. Weight, backfat, and longissimus muscle area at 226 days of age, and age at puberty.[a,b]

	Weight, kg		Backfat, cm		Longissimus area, cm^2		Age at puberty, days	
Item	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
LW x LR	128.1	2.06	2.32	0.15	40.6	1.05	178.6	3.33
L45X	124.1	2.10	2.44	0.14	39.2	1.05	173.0	3.34
P-value	0.0025		0.048		0.002		0.003	
A	137.3	2.04	2.88	0.14	42.6	1.04	174.1	3.27
R	115.0	2.04	1.89	0.14	37.3	1.04	177.5	3.29
P-value	<.0001		<.0001		<.0001		0.017	

[a]LW x LR = Large White x Landrace cross females, L45X = Line 45 cross females.
[b]A = ad libitum access to feed to breeding age (230 days), R = energy restriction (75% of A) from 123 to 230 days of age.

be coded as 1 (success) or 0 (failure). Gilts completing the growth test were coded as 0 if they did not express a pubertal estrus and 1 if they did. Then, based on females designated for breeding, they were coded as 1 or 0 if they did or did not produce litters at each of parities 1 to 4. Each female received four scores. A gilt designated for breeding that did not produce a P1 litter received scores of 0, 0, 0, 0 for reproductive success at each parity. One that produced a P1 litter, but not a P2 litter, received scores of 1, 0, 0, 0; one that produced two litters received scores of 1, 1, 0, 0, etc., and one that produced four litters received scores of 1, 1, 1, 1. These scores measure reproductive success rates. They were fitted with general linear models designed for binomial data to determine the importance of line, gilt treatment, and interaction of line with treatment on reproductive rate through 4 parities. The effects of replication, sire, and litter of gilt were fitted in models as random effects to account for those sources of variation.

Number of live pigs per litter and number and total weight of pigs weaned by each sow were analyzed with models that included line, treatment, interaction, and random effects of replication, sire, and litter of gilt. Number of pigs that sows were given an opportunity to raise (number after crossfostering) and age at weaning were included as covariates to adjust all sows to a common number nursed and lactation length. Lifetime productivity of each female designated for breeding was calculated as the total number of live pigs, total number of weaned pigs, and total weight of pigs at weaning that she produced through parity 4. These measures of lifetime production were fitted to the same model as described above.

Results

Table 1 contains the numbers of pigs at each stage during the gilt developmental period. Of the total 661 gilts that started the experiment at 60 days of age, 9 died between 60 and 123 days and 13 died or were removed for structural or health reasons between 123 and 226 days of age. These losses were approximately equal across lines and treatments. Of the 639 gilts that completed the developmental period, 568 expressed a pubertal estrus by 230 days of age when gilts were moved to the breeding barn; 15 of these gilts were culled because they expressed estrus very late in this period and could not be mated at second or greater postpubertal estrus. Line and treatment affected both age at puberty and the proportion of gilts that expressed pubertal estrus (see below for results of analysis). Eleven gilts that expressed estrus either died or were culled for structural or health reasons before breeding, and an additional 33 gilts that qualified as breeders were culled at random to reduce the numbers to available breeding and farrowing spaces. A total of 509 gilts were designated as breeders, and it is these gilts for which lifetime production scores and productivity were recorded and analyzed.

The *2008 Nebraska Swine Report* contains articles summarizing effects of line and gilt developmental regimen on growth of gilts to 226 days of age and

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Table 3. Number of gilts that produced litters at each parity and numbers removed for reproductive failure, death, or unsoundness.[a]

		Parity 1							Parity 2						
Line	Trt	Brds	No. Lits	Mated open	Cull no est	Died gest	Cull FL/Inj	Died far	Brds	No. Lits	Mated open	Cull no est	Died gest	Cull FL/Inj	Died far
		Parity 1							Parity 2						
LW x LR	A	139	107	22	8	2	0	4	103	63	16	17	7	0	0
LW x LR	R	123	97	16	5	2	3	1	96	65	16	14	1	0	1
L45X	A	129	112	15	1	1	0	1	111	63	24	24	1	0	1
L45X	R	118	96	13	4	4	1	0	96	65	15	10	5	1	0
Total		509	412	66	18	9	4	6	407	256	71	65	14	1	2
		Parity 3							Parity 4						
LW x LR	A	63	53	8	2	0	0	0	54	41	12	1	0	0	0
LW x LR	R	64	51	10	2	1	0	0	51	41	8	1	1	0	0
L45X	A	62	51	6	4	0	1	0	51	44	7	0	0	0	0
L45X	R	65	56	5	3	1	0	1	55	44	7	3	1	0	0
Total		254	211	29	11	2	1	1	211	170	34	5	2	0	0

[a]Brds = Number of females designated as breeders; No. lits = number of litters; Mated open = number mated but culled because they were diagnosed as not pregnant; Cull no. est = number that were culled because they did not express estrus during the breeding period; Died gest = number died during gestation, Cull FL/Inj = number culled for foot and leg or other soundness condition; Died Far = number that died during farrowing.

Table 4. Probability of reproductive success.

	Pr Pub Estrus[a]		Pr P1 Litter[b]		Pr P2 Litter[b]		Pr P3 Litter[b]		Pr P4 Litter[b]	
Item	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Line means										
LW x LR	0.88	0.034	0.78	0.038	0.49	0.057	0.40	0.073	0.31	0.073
L45X	0.95	0.019	0.84	0.032	0.52	0.057	0.43	0.075	0.34	0.078
P-value	0.010		0.076		0.633		0.562		0.436	
Treatment means										
A	0.96	0.016	0.83	0.034	0.47	0.056	0.38	0.072	0.31	0.073
R	0.86	0.037	0.80	0.037	0.54	0.057	0.44	0.075	0.34	0.078
P-value	0.0001		0.521		0.135		0.203		0.386	

[a]Probability that gilts that completed the development period expressed pubertal estrus by 225 days of age.
[b]Probability that gilts identified as breeders produced parity 1, 2, 3, and 4 litters.

age at puberty. To illustrate effects of line and treatment on growth, mean final weight, backfat, longissimus muscle area, and age at puberty are in Table 2. Lines responded similarly to treatment as interaction of line by treatment was not significant for any trait. LW x LR gilts were 4 kg heavier with 0.12 cm less backfat and 1.4 cm^2 greater LMA than L45X gilts (all $P < 0.05$). L45 X gilts were 5.6 days younger ($P < 0.01$) at puberty than LW x LR gilts. Treatment effects were significant for all traits. Developing gilts with 25% energy restriction caused them to weigh 22.4 kg less, to have .99 cm less backfat and 5.3 cm^2 less LMA, and to be 3.4 days older at puberty than developing them with ad libitum access to feed.

Table 3 contains the number of females that produced litters at each parity, number of sow deaths, and the number of sows culled for reproductive failure, health and structural conditions. Most sow losses were those that were mated and subsequently returned to estrus. Overall, the percentages of breeding females that fit that category were 13, 17, 11, and 16% at parities 1 to 4, respectively. The incidence of culling for return to estrus after insemination during the breeding period did not differ significantly between lines or treatments, although it was somewhat greater for LW x LR than L45X sows (16 vs. 13%) and for gilts developed with restricted energy intake than those fed ad libitum (13.5 vs. 10.3%).

The second most frequent cause of culling sows was failure to express estrus during the breeding period, which includes those that may have expressed an estrus that was not detected by technicians. The incidence of that condition was low in gilts (3.5%), quite high for parity 1 sows being mated for parity 2 litters (16%), and low again for mating of parity 2 and 3 sows for their next litter (4.3 and 2.4%, respectively).

In many production herds, sows that return to estrus after insemination are often inseminated again and given another chance to reproduce, and some with delayed returns to estrus are eventually inseminated and conceive. These practices would lead to more lit-

Table 5. Mean number of live pigs, number weaned, and litter weaning weight for females with litters, per female with litter, and lifetime productivity per gilt designated for breeding.

			Number of live pigs		Number weaned		Litter weaning weight, kg	
Line[a]	Trt[b]	Parity	Mean	SEM	Mean	SEM	Mean	SEM
LW x LR			11.73	0.31	10.01	0.11	55.3	0.9
L45X			12.13	0.31	9.76	0.11	52.8	0.9
	A		11.90	0.31	9.82	0.11	53.4	0.9
	R		11.96	0.31	9.95	0.11	54.7	0.9
		1	11.74	0.30	10.08	0.10	50.5	0.9
		2	11.53	0.32	10.20	0.12	57.8	1.0
		3	12.20	0.33	9.95	0.13	55.9	1.0
		4	12.24	0.35	9.32	0.14	51.9	1.1
P-values for line, treatment, and parity effects								
Line			0.12		0.05		0.008	
Trt			0.81		0.27		0.13	
Parity			0.02		<.0001		<.0001	
Lifetime production per gilt designated for breeding								
LW x LR			23.37	3.32	19.48	2.69	106.2	16.3
L45X			26.05	3.33	21.12	2.70	112.9	16.3
	A		23.83	3.30	19.60	2.69	105.4	16.2
	R		25.59	3.32	21.00	2.71	113.8	16.3
P-values for lifetime production								
Line			0.14		0.25		0.41	
Trt			0.31		0.32		0.28	

[a]LW x LR = Large White x Landrace cross females; L45X = Line 45 cross females.
[b]A = ad libitum access to feed to breeding age (230 days); R = energy restriction (75% of A) from 123 to 230 days of age.

ters from the same set of females than in this experiment, in which these sows were all culled and not given another chance to reproduce. To ensure a uniform culling policy for all replications, parities, lines, and treatments, we determined that those sows would be culled. Also, giving the sows additional opportunities to reproduce extends the farrowing period, which did not fit our production schedule.

Of the 509 gilts designated for breeding, 27 (5.3%) died during one of the four gestation periods and 9 (1.8%) died during farrowing. Very few sows were culled for foot and leg or health conditions.

Table 4 contains results of statistical analysis of the 0/1 binomial scores for reproductive success. The analysis produced the probability statistics in the table. The first of these is the probability that a gilt that finished the development period expressed estrus by 230 days of age. Both line and treatment significantly affected this probability; 95% of L45X gilts reached puberty compared with 88% of LW x LR gilts ($P = 0.01$), and 96% of gilts developed with ad libitum intake reached puberty compared with 86% of gilts developed with energy restriction ($P = 0.0001$). Gilts of both lines responded similarly to treatments as there was no interaction.

Probabilities of females producing parity 1 to 4 litters are all based on gilts designated as breeders at 230 days of age. No effect, line, treatment, or interaction, was significant for any of these probabilities. The greatest difference was between lines for the probability that gilts designated as breeders produced a parity 1 litter, being .84 for L45X gilts and .78 for LW x LR gilts (P = 0.076). The probability that females produced parity 2, 3, and 4 litters was greater for those developed with restricted energy intake, but none of these differences approached statistical significance ($P > .10$).

Although not significant, line differences in this experiment are consistent with differences observed in previous comparisons. Line 45X females had 0.4 more live pigs per litter than LW x LR females, but their maternal abilities were not as good. When given an opportunity to raise the same number of pigs, LW x LR females weaned 0.25 more pigs per litter and total litter weight was 2.5 kg more than for L45X females. Gilt development regimen had almost no effect on subsequent litter size or maternal ability in either line as interaction of line and treatment was not significant.

All measures of lifetime production were greater for L45X females than LW x LR females and for females developed with restricted energy intake (Table 5). However, none of these measures, total number of live pigs at birth, total number weaned, nor total weight of litter weaned, all calculated per gilt designated for breeding, was significantly affected by line, treatment, or interaction. Lifetime sow productivity is a difficult trait to evaluate experimentally. The observed differences were relatively large, ranging from 8 to 11%, and if real, are economically important. Yet, in an experiment in which 509 females produced 1,049 litters and in which variation was controlled and culling criteria strictly adhered to, natural variation was still large enough that observed differences could be explained by chance as all *P*-values were > = 0.14.

Thus, we conclude from this project that prolific gilts that differ in rate of lean growth respond similarly to a developmental regimen in which energy intake from 123 days of age to breeding was restricted to 75% of that of gilts developed with ad libitum intake. Further, this energy restriction decreased the proportion of gilts that had expressed estrus by 230 days of age and increased the age at puberty for those that did express pubertal estrus. Thereafter, females developed with both regimens had similar reproductive performance at each parity and similar lifetime production.

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