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Housing and management aspects influencing gilt development and longevity: A review

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Introduction

A small amount of scientific information is available on causes of culling replacement gilts. A study in Sweden indicated that 54.5% of gilts selected for breeding purposes at 10 weeks of age were culled without having farrowed a litter. The frequency and causes of culling replacement gilts are indicated in **Table 1**.[1] It is economically important to develop replacement gilts for longevity, because the cumulative relative cost per piglet increases by 21% and 10% if sows are culled at their first or second litter instead of their seventh litter.[2]

Sexual development and longevity of replacement gilts can be affected by housing features (structural and spatial), climatic environment, manure handling systems, feeding systems, nutrition programs, and numerous management factors. Some of these factors are critical control points and need careful consideration when developing a total quality management program for replacement gilts. The purpose of this paper is to present a review of literature on how various housing and management factors effect puberty attainment and longevity of replacement gilts. The effect of nutritional aspects on sexual development and longevity of replacement gilts has been presented in another paper in these *Proceedings*; thus, below I have omitted how nutrition effects sexual development and longevity of replacement gilts.

Although replacement gilts can enter a herd at various ages and methods, they need to be managed correctly from birth through their first lactation. The successful development of replacement gilts requires the integration of health, nutrition, genetics, housing, and management practices. Thus, an excellent gilt development program will reduce replacement costs of multiparous sows. It is beyond the scope of this paper to discuss how all the housing and management factors in each phase of the gilt's life can influence reproductive performance and longevity. A very small amount of research has been conducted to determine whether various factors occurring during the nursery and grower phase influence puberty attainment and lifetime reproductive performance. The affect of various factors occurring from birth to 160 days of age on puberty attainment has been briefly presented in other publications.[3,4] The remaining portion of this paper contains information on how various aspects that occur from about 70 days of age onward influence puberty attainment.

Factors influencing gilt development and longevity

Genetics

It is well known that genetics has an affect on age, weight, and backfat at puberty.[5,6] Backfat thickness at 198 pounds of body weight and growth rate from 55 to 198 lb. were

Table 1: Reasons for culling selected replacement gilts

Reason for culling	Number of culled gilts	Percentage of selected gilts culled[a]	Percentage of recruited gilts culled
Slow growth rate	162	14.6	7.9
High backfat thickness	308	27.7	15.1
High backfat thickness & inverted teats	76	6.8	3.7
Inverted teats	130	11.7	6.4
Anestrus	122	11.0	6.0
Repeat breeding	34	3.0	1.7
Not pregnant	73	6.6	3.6
Abortion	11	1.0	0.5
Miscellaneous	196	17.6	9.6
Total	1112	100.0	54.5

[a]Gilts were selected at 10 weeks of age

found to be negatively correlated with age at puberty; however, backfat thickness at puberty had no influence on puberty attainment.[7] Genetic improvement has significantly changed the body composition of modern crossbred gilts. The modern gilt can be very lean (0.44 to 0.70 inches of backfat) when first estrus occurs between 203 and 260 days of age (**Table 2**).[8-11] The consequences of genetic change in the crossbred gilt include the following:

- Increased daily lean tissue deposition
- Lower backfat
- Lower appetite
- Increase in age at puberty
- Increase in body weight at puberty
- Prolonged weaning-to-estrous interval
- Increased returns to first mating
- Lower second litter size
- Inferior lifetime performance
- Increased culling at an earlier age

The housing and management aspects for rearing genetically lean replacement gilts is most likely not the same as required for genetically "fatter" gilts. It needs to be kept in mind that most of the scientific studies reviewed for this paper used fatter gilts.

Air quality

The control of air quality is an important aspect of environmental management of swine facilities. The quality of air within a swine facility depends on moisture level, concentration of toxic gases, concentration of microorganisms, and concentration of solid airborne particles. The effects of air quality on the health of pigs and humans are related to the complex action of particles and gases as well as the physical environment.[12,13] Although a maximum concentration of 7.5 ppm of ammonia is recommended as a target for the occupational health of people working with pigs,[14] the concentration of ammonia within a finishing facility can be greater than 10 ppm.[15] Research has revealed that sustained exposure to ammonia concentrations greater than 10 ppm is aversive to pigs.[16] However, if pigs are given a choice between an environment that is below their lower critical temperature (LCT) or a heated-polluted environment of 40 ppm ammonia, the pigs will pick the warmer environment.[17]

Is age at puberty compromised when gilts are reared in an aversive gaseous environment? A greater proportion of gilts exposed to 5 ppm ammonia from 10 to 37 weeks of age attained puberty by 168 to 182 days of age ($P<.05$) and 189 to 192 days of age ($P<.10$) compared to gilts exposed to 21 ppm ammonia (**Table 3**).[18] A greater proportion of gilts exposed to 5.7 ppm ammonia from 10 to 28 weeks of age attained puberty by 7 days ($P<.05$) and 10 days ($P<.07$) after starting boar exposure compared to gilts exposed to 19.7 ppm ammonia (**Table 4**).[19] When gilts were first exposed at an older age (18 weeks) to 35 ppm ammonia, age at puberty was similar compared to gilts exposed to 7 ppm ammonia (**Table 5**).[20] However, the gilts exposed to 7 ppm ammonia were 20 pounds heavier at puberty. Body weight of gilts exposed to 35 ppm ammonia was severely depressed during the initial 2-week exposure period. Although not statistically different, gilts exposed to 7 ppm ammonia had one more pig and their fetuses weighed four grams more than fetuses by gilts exposed to 35 ppm ammonia. This data would suggest that air quality has more of an effect on younger gilts than older gilts.

Ambient temperature

Elevated ambient temperatures during the summer months often cause transient periods of infertility in replacement gilts. The data in **Table 6** indicates that a lower proportion of gilts came into estrus during July and August; however, litter size was not affected for gilts bred during July and August.[21] A University of Missouri study found that a

Table 2: Age, body weight, and backfat of gilts when first detected in estrus

Reference	Average age, days	Average body weight, lbs	Average backfat, in.
Ogle and Dalin, 1989	260.5	216.7	0.55
	258.2	195.9	0.57
LeCozler et al., 1998	234.5	330.9	0.62
	247.0	293.2	0.44
LeCozler et al., 1999	198.1	279.3	0.70
	203.2	257.9	0.58
Cameron et al., 1999	224.0	271.2	0.57
	234.0	264.5	0.50
	206.0	244.7	0.59

Table 3: Effect of ammonia concentration on puberty attainment in gilts

	Concentration of ammonia, ppm[a]		
Cumulative percentage of gilts cycling by:	**4.8±1.4**	**21.1±3.8**	**P value**
Number gilts	42	41	-
168 days	16.7	4.9	<.05
175 days	16.7	4.9	<.05
182 days	19.0	4.9	<.05
189 days	23.8	7.3	<.10
196 days	28.6	9.8	<.10
203 days	35.7	19.5	Nonsignificant
210 days	35.7	46.3	Nonsignificant
245 days	64.3	60.9	Nonsignificant
280 days	85.9	85.0	Nonsignificant

[a]Age of gilts was 10 to 37 weeks.

Table 4: Cumulative proportion of gilts attaining puberty by day after initiating boar exposure

	Concentration of ammonia, ppm[a]		
Cumulative percentage cycling by day after starting boar exposure	**5.7±6**	**19.7±2.7**	**P value**
Number of gilts	42	42	-
7 days	11.9	0.0	<.05
10 days	28.6	9.5	<.07
13 days	42.9	33.3	Nonsignificant
16 days	45.2	40.5	Nonsignificant
20 days	50.0	45.2	Nonsignificant
24 days	59.5	50.0	Nonsignificant
27 days	64.3	50.0	Nonsignificant

[a]Age of gilts was 10 to 28 weeks.

Table 5: Effect of concentration of ammonia on age at puberty, weight at puberty, and reproductive traits

	Concentration of ammonia, ppm[a]		
	6.7±1.0	**34.5±2.5**	**P value**
Number of gilts	40	40	
Age at puberty, days	208	205	Nonsignificant
Weight at puberty, lbs	260.5	241.4	<.05
Conception rate, %	94.1	100.0	Nonsignificant
Number corpora lutea	13.9	13.4	Nonsignificant
Number Live fetuses	11.7	10.6	Nonsignificant
Total weight of fetuses, grams	17.1	13.7	Nonsignificant

[a]Age of gilts was 18 to 24 weeks.

Table 6: Reproductive performance of a gilt pool

Month	Number gilts selected[a]	Gilts cycling & mated, %	Farrowing rate, %	Litter size	
				Alive	Total
January	45	82.2	86.5	9.50	9.93
February	45	75.6	82.4	8.57	9.25
March	45	77.8	80.0	8.39	8.78
April	45	80.0	97.2	8.83	9.23
May	45	84.4	81.6	9.48	10.00
June	45	73.3	93.9	9.54	9.93
July	45	57.8	80.8	9.19	9.57
August	45	44.4	80.0	9.25	9.68
September	45	75.6	85.3	9.10	9.48
October	45	82.2	86.5	9.31	9.59
November	45	86.7	84.6	9.27	9.57
December	45	77.8	85.7	9.06	9.46
Overall	540	74.8	85.7	9.13	9.54

[a]Gilts were 6 to 6.5 months of age at selection.

chronic heat-stress (91.9° F) from 150 to 230 days of age caused 80% of the gilts to not cycle and nonsignificantly reduced ovulation rate at puberty (12.1±2.5 vs. 9.3±5.1; P>.05).[22] Heat-stress appears to diminish the secretion of gonadotropins (LH and FSH), cause an increases plasma levels of cortisol, and a rapid increase in PGF-2α.[23-25] Exposure of "cyclic" gilts to heat-stress (95° F for 10 hours) produced an abnormal second estrus in 42.9% (3 of 7) of gilts in Thailand; however, a heat-stress of 95° F for 17 hours in Australia did not produce an abnormal estrus cycle between the third and fourth estrus of 24 gilts.[26,27] This data would suggest that heat-stress has more detrimental effects on younger gilts than older gilts.

What type of cooling system do gilts prefer? When gilts were housed on an expanded metal floor during heat-stress (93.5° F for 10 continuous hours), the gilts preferred to use a conductive cool pad over a drip cooler (P<.02) or snout cooler (P<.0002).[28] The cooling of gilts by wetting them with a hose for 2.5 minutes each hour from 10:00 AM to 4:00 PM during heat-stress (96.4° F) resulted in cool gilts having a lower respiratory frequency (84 vs. 109 breaths per minute; P<.05), a higher feed intake (4.3 vs. 3.8 lb./day; P<.05), a better feed conversion (4.1 vs. 12.5 lb. feed/lb. gain), and gaining 0.77 lb. per day more (1.08 vs. .31 lb./day; P<.10) compared to non-cooled gilts.[29]

Photoperiod

The influence of photoperiod on age of puberty and proportion of gilts reaching puberty remains controversial. Many scientific studies used boar exposure to detect estrus when evaluating the effect of photoperiod on puberty attainment; thus, the true effect of photoperiod can not be determined. **Table 7** indicates the proportion of gilts reaching puberty is greatest when gilts are exposed to mature boars, regardless of whether duration of day light is increasing or decreasing.[30-32] With very small data sets, Canadian research has shown that age at puberty and ovulation rate is not different between gilts exposed to 10.8 hours of light per day and those exposed to 18 hours of light per day (**Table 8**).[33,34] Neither type of lighting (fluorescent or incandescent) nor intensity of light (lux) significantly influences puberty attainment in gilts. A higher ovulation rate has been reported for gilts kept under broad spectrum light compared to cool white light (13.4 vs. 11.3; P<.02). These data suggest that the most economical lighting program for developing gilts is to use 10 to 12 hours per day of broad spectrum light (270 to 500 lux).

Boar effect

It is well known that exposure of prepubertal gilts to mature boars will stimulate puberty in replacement gilts. Although most of the components of the boar effect (sight, sound, smell, and physical contact) interact to stimulate puberty in gilts, I have chosen to partition this topic as follows:

- Age of gilt at first boar exposure
- Age and sexual behavior of boars
- Type of boar contact
- Frequency of boar contact
- Duration of boar contact

Age of gilt at first boar exposure

The age of gilt at first boar contact is the single most important factor influencing the degree of response to stimulate and synchronize pubertal estrus. Research data indi-

Table 7: Proportion of gilts reaching puberty when the duration of daylight is increasing or decreasing

Reference	Duration of daylight is increasing		Duration of daylight is decreasing	
	Boar exposure[a]	**No boar exposure**	**Boar exposure**[a]	**No boar exposure**
Paterson et al., 1991	74.0	13.9	89.4	52.6
Paterson et al., 1990	72.4 (195)[b]	2.9 (227)	62.1 (196)	54.1 (212)
Diekman and Hoagland, 1983	79.0 (192)	31.0 (200)	80.0 (205)	12.0 (199)

[a]Age of gilts at start of boar exposure was 165 to 173 days.
[b]Number in parentheses is average age at puberty in days.

Table 8: Effect of light on age at puberty and ovulation rate

Item	Hours of light per day		
	0	**9 to 10.8**	**18**
Ntunde et al., 1979			
Number of gilts	12	12	12
Age at puberty, days	193.4[a]	175.6[b]	177.1[b]
Number corpora lutea	12.3	12.4	13.3
Hacker et al., 1979			
Number of gilts	6	6	6
Age at puberty, days	200.5[a]	164.8[b]	175.3[b]
Number corpora lutea	11.3[a]	13.5[b]	12.6[a,b]

[a,b]Means in the same row with different superscripts differ ($P<.05$)

cates that the best time to start boar exposure for crossbred gilts is between 150 to 170 days of age. The optimum age range to start boar exposure for purebred and late maturing animals is most likely 170 to 190 days of age. If boar exposure is started about two to three weeks before expected date of puberty, a higher percentage of gilts will cycle and be more synchronized. Thus, pork producers need to know the average age of puberty for their replacement gilts. The age at puberty for all gilts in the gilt pool can be quite variable (**Table 9**).[7,35,36]

Age and sexual behavior of boar

Younger boars do not secrete adequate levels of pheromones; thus, boars used to stimulate puberty in replacement gilts should be a minimum of 10 months of age and have a high level of sexual behavior. Research has indicated that boars with a high level of sexual behavior will stimulate puberty in gilts about 9 to 15 days earlier than low sexual behavior boars (**Table 10**).[37,38] The proportion of gilts reaching puberty within 20 days after starting boar exposure will be higher for gilts exposed to high sexual behavior boars compared to low sexual behavior boars (59% vs. 19%; $P<.05$).

Type of boar contact

From a worker's standpoint, it is much easier to heat-check gilts by fenceline boar contact instead of placing the boar in the gilt pen for full boar contact. However, fenceline contact with a boar is inadequate to stimulate puberty in most gilts (**Table 11**).[39-42] In addition, full boar contact is needed when gilts are taken to a high stimulation area that only houses boars (**Table 12**).[43] When gilts were taken to high stimulation environment (boar house), a higher percentage of gilts cycled within 220 days of age when given full boar contact compared to fenceline contact (79% vs. 41%; $P<.05$). This data supports earlier work that indicated a higher proportion of gilts will cycle when they were taken to boar pens instead of taking the boar to the gilt pens (Scheimann et al., 1976: 78% vs. 46%; Van Lunen & Aherne, 1987: 68% vs. 48%).[44,45]

Frequency of boar contact

Managers of breeding facilities are always looking for ways to increase the efficiency of their unit with a minimal amount of labor and time. Large swine enterprises have a tendency to only heat-check replacement gilts once per day.

Does the number of times per week of boar contact influence age at puberty and proportion of gilts cycling? The effect of exposing gilts to boars either 2, 5, or 7 days per week is indicated in **Table 13**.[46] The frequency of boar exposure did not affect the proportion of gilts cycling during the spring, summer, or autumn months. However, the interval from the start of boar exposure until the gilts

Table 9: Average age, standard deviation, and range in age at puberty of gilts

Reference	No. gilts	Genetics[a]	Average age at puberty, days	SD	Range in age at puberty	
					Youngest	Oldest
Johnson, 1988	244	LW x LR	180	23.8	135	276
Eliasson et al., 1991	481	SY	211	19.8	156	261
Rozeboom et al., 1995	93	LR x Y	173	26.3	138	240

[a]LW, Large White; LR, Landrace, SY, Swedish Yorkshire; Y, Yorkshire

Table 10: Effect of boar libido on average age at puberty of gilts

Reference	High libido boars	Low libido boars	No boar exposure
Hughes, 1994	179.6[a]	194.1[b]	209.1[c]
Zimmerman et al., 1997	164.4[A]	173.3[B]	194.0[C]

[a]vs[b]: Means are different (P<.05)
[a]vs[c]: Means are different (P < .01)
[b]vs[c]: Means are different (P<.05)
[A]vs[B]: Means are different (P<.06)
[A and B]vs[C]: Means are different (P<.01)

Table 11: Effect of fenceline or full boar contact on age at puberty or percentage cycling in gilts

Reference	Full boar contact	Fencelinec ontact	No boar contact	P value
Karlbom, 1981/82	163[a]	183[b]	198[c]	<.01
Deligeorgis et al., 1984	167.9[a]	192.2[b]	191.2[b]	<.01
Zimmerman et al., 1996	187.0[a]	198.9[b]	-	<.02
Pearce & Paterson, 1992	80%[a]	38%[b]	21%[b]	<.01

Table 12: Effect of type and location of boar contact on percentage of gilts attaining puberty by 220 days of age

Type of boar exposure	Location of boar exposure		Average
	Isolated pen	Boar housing area	
Fenceline contact	41%	50%	45.5%
Full boar contact	59%	79%	69.0%
Average	50.0%	64.5%	

Table 13: Effect of frequency of boar contact per week and season on puberty attainment in gilts

	Spring months		Summer months		Autumn months		Average	
Boar contact	% cycled	Days to pub'ty	% cycled	Days to pub'ty	% cycled	Days to pub'ty	% cycled	Days to pub'ty
2 d/wk	88.9	32.5[a]	88.9	36.0	87.5	33.0[a]	88.5	33.8
5 d/wk	100.0	18.5[b]	100.0	34.5	87.5	34.0[a]	96.0	29.0
7 d/wk	100.0	16.5[b]	87.5	29.0	87.5	11.5[b]	92.0	19.0
Average	96.3	22.5	92.1	33.2	87.5	26.2		

[a,b]Means with different letters differ (P<.05).

attained puberty was better when boar exposure occurred seven days per week, especially during the spring and autumn months. It has been shown that providing only 10 consecutive days of boar contact to a group of gilts will stimulate puberty; however, daily boar exposure until puberty was necessary for maximum stimulation of puberty during the summer months (**Table 14**).[47] Providing gilts with boar exposure every other day was found to be inadequate to stimulate puberty attainment compared to daily boar exposure (Zimmerman et al., 1991: 181.1 vs. 199.4 days of age at puberty, P<.01; Hughes, 1994: 186.1 vs. 195.3 days of age, P>.05).[48,49]

The next question would be, Does the number of times per day of boar exposure enhance puberty attainment of gilts? Researchers have found that a higher percentage of gilts will attain puberty at a younger age when provided boar contact two to three times per day compared to once per day (**Table 15**).[49-51] The effect of frequency (once or twice per day) and type (full boar vs. fenceline) of boar contact on puberty attainment is indicated in **Table 16**.[52,53] Two exposures per day reduced the interval from first boar exposure to puberty when the gilts were 154 (18.6 vs. 24.8; P .05) or 160 (21.5 vs. 28.4; P<.08) days of age at start of boar exposure; however, frequency of boar exposure did not affect the interval to puberty when gilts were 130 days of age at beginning of boar exposure. The proportion of gilts cycling during the first 10 days of boar exposure was significantly higher when gilts (160-day old gilts) were exposed to full boar contact twice per day (54%) compared to full boar contact once per day (27.3%), fenceline contact once per day (13.6%) or fenceline contact twice per day (21.7%). The proportion of gilts (160-day old gilts) cycling by 30 days after starting boar exposure was 64.5% for gilts provided fenceline contact twice per day compared to 34.1% for fenceline contact once per day. This data suggests that to maximize the boar effect replacement gilts should be given full boar contact twice per day.

Duration of boar contact

For the boar to satisfactorily stimulate each gilt he needs to have: (a) sufficient time to interact with all the females in the group, and (b) sufficient space for effective interaction with the gilts. This implies that time allocation, group size, and number of gilts per group will all have moderating effects on stimuli provided by the boar. The main effect of each factor is difficult to determine from previous research because most of the studies have confounded two or more of the factors. The affect of duration of boar exposure on puberty attainment in gilts is indicated in **Table 17**.[41,47,54,55] These data indicate that 10 to 15 minutes of full boar exposure should be adequate to stimulate puberty in gilts. The low response of gilts cycling in the study by Caton (1986) is most likely due to the young age of boars used (six months) to stimulate puberty. Although the alteration in the number of gilts in the exposure group (2, 4, or 8) or the size of exposure pen (117.2 ft^2 or 234.5 ft^2) changed the frequency of boar-to-gilt interactions, neither the number of gilts per exposure group or size of exposure pen significantly affected average age at puberty, proportion of gilts attaining puberty, or the interval from first boar contact to puberty.[56]

Table 14: Effect of boar stimulation and season on percentage of gilts attaining puberty

	Winter months	Summer months
Medina Research Facility		
10 continuous days	100%	66.7%
Daily until puberty	100%	100.0%
Muresk Research Facility		
10 continuous days	100.0%	37.5%
Daily until puberty	87.5%	87.5%

Table 15: Effect of boar contact frequency on attainment of puberty in gilts

	Number of times per day of boar exposure		
	One	Two	Three
Hughes, 1994			
Season: Winter			
Age of boars	>12 months	>12 months	>12 months
Time per exposure	60 minutes	30 minutes	20 minutes
Type of boar exposure	Full boar	Full boar	Full boar
Number of gilts	16	16	16
Age of gilt at start, days	160.3	160.3	160.3
Age at puberty, days	188.8[ab]	196.1[a]	177.9[b]
Interval to puberty, days	27.8 [ab]	35.4 [a]	17.8 [b]
Cycling by 20 days	31%	26%	62%
Philip & Hughes, 1995			
Season: All seasons			
Age of boars	>12 months	>12 months	>12 months
Time per exposure	60 minutes	30 minutes	20 minutes
Type of boar exposure	Full boar	Full boar	Full boar
Number of gilts	32	31	32
Age of gilt at start, days	160	160	160
Age at puberty, days	196.0 [a]	190.3 [ab]	183.2 [b]
Interval to puberty, days	36.8 [a]	30.6 [ab]	23.7 [b]
Cycling by 20 days	6.0 [A]	16.0 [AB]	28.0 [B]
Hughes et al., 1997			
Season: Autumn			
Age of boars	>12 months	-	>12 months
Time per exposure	20 minutes	-	20 minutes
Type of boar exposure	Full boar	-	Full boar
Number of gilts	16	-	16
Age of gilt at start, days	160	-	160
Age at puberty, days	178.7	-	183.1
Cycling by 40 days	25.0%	-	44.0%

[ab]Means within row with different superscripts differ (P<.01).
[AB]Means within row with different superscripts differ (P<.05).

Estrous sow or gilt effect

Scientists have investigated whether mature sows will stimulate puberty attainment in gilts.[57,58] It was found that estrous sows can stimulate puberty in gilts; however, the response generally takes longer and the response is not as high as with a mature boar. It has also been reported that synchrony of puberty in gilts is significantly improved (P<.01) when cyclic gilts remain in their group after puberty or second estrus than among pens of gilts in which the estrus gilts are removed from the pen at first detected estrus.[57]

Transport phenomenon

The so-called non-boar management "stressors" that stimulate puberty attainment in replacement gilts are mixing, relocation, transport, and a combination of these factors. The results of these stressors, when used individually or in combination, have been highly variable. A study in France found that the combination of transport + boar exposure + new environment induced estrus in 72.6% (363 of 500) of the gilts within seven days after being transported 100 miles.[59] This study also found that neither age at transport (130 to 194 days of age) nor season influenced the induction of puberty. The percentage of gilts cycling within seven days was influenced (P<.01) by sire of the gilts (Sire 1, 51.0%; Sire 2, 59.1%; Sire 3, 68.9%; Sire 4, 73.5%).[59] A sire effect is not surprising because the heritability of age at puberty is 0.29 to 0.32.[5,6] An Australian study found that transport alone (20 minutes per day for 10 consecutive days) did not provide a significant stimulus for puberty attainment in gilts; however, transport + frequent boar contact (three times per day) resulted in a shorter interval from start of boar exposure until puberty than frequent boar contact alone (24.7 vs. 37.4 days; P<.05).[50]

Table 16: Effect of frequency and type of boar contact on puberty attainment

	Frequency of exposure^A			
	Once/day	**Twice/day**	**Once/day**	**Twice/day**
Zimmerman et al., 1998				
Age of boars	>10 months	>10 months	>10 months	>10 months
Time per exposure	10 minutes	10 minutes	10 minutes	10 minutes
Type of boar exposure	Full boar	Full boar	Fenceline	Fenceline
Number of gilts	30	30	30	30
Age of gilt at start, days	160	160	160	160
Age at puberty, days^a	184.3	180.3	197.9	184.9
Interval to puberty, days^b	20.9	19.6	36.0	23.4
Cycling by:				
10 days	27.3%	54.0%	13.6%	21.7%
20 days	71.7%	65.6%	29.8%	55.4%
30 days	80.2%	78.1%	34.1%	64.6%
Zimmerman et al., 2000				
Age of boars	16 months	16 months	16 months	16 months
Time per exposure	10 minutes	10 minutes	10 minutes	10 minutes
Type of boar exposure^B	Full boar	Full boar	Fenceline	Fenceline
Number of gilts	32	32	32	32
Age of gilt at start, days^C	130	130	130	130
Age at puberty, days	157.2	168.5	175.6	170.6
Interval to puberty, days	24.6	36.2	42.4	37.6
Cycling by 21 days, %	43.0	24.0	5.0	30.0
Age of gilt at start, days	154	154	154	154
Age at puberty, days	177.6	172.3	179.5	172.1
Interval to puberty, days	24.2	19.1	25.5	18.2
Cycling by 21 days, %	56.0	70.0	56.0	82.0

[a]The overall main effect of full boar exposure reduced age at puberty (182.6 vs. 191.4; P<.02).

[b]The overall main effect of two exposures per day reduced interval to puberty (21.5 vs. 28.4; P<.08)

[A]For Zimmerman, et al., 2000, the overall main effect of two exposures per day reduced the interval to puberty for gilts exposed to boars starting at 154 days of age (18.6 vs. 24.8; P<.05) compared to one exposure per day; however, frequency of boar exposure did not affect the interval to puberty for gilts exposed at 130 days of age.

[B]The overall main effect of full boar exposure lowered the interval to puberty (26.0 vs. 30.9; P<.11) and average age at puberty (168.9 vs. 174.5; P<.08).

[C]The overall main effect of starting boar exposure at 154 days of age reduced the interval to puberty compared to 130 days of age (21.8 vs. 35.2 days; P<.01). The overall average at puberty was lower when boar exposure started at 130 days of age compared to 154 days of age (168.0 vs. 175.4 days; P<.01).

Age, weight, backfat, and estrous number at mating

The effect of age, weight, backfat, and estrous number at mating on lifetime reproductive performance was presented at the 1996 Allen D. Leman Swine Conference.[60] One absolute recommendation cannot be given because of numerous factors such as genetics, housing environment, and management and nutrition practices used during the growing and developing phase, gestation phase, and lactation phase. The age, body weight, backfat thickness, and estrous number at mating should be specifically determined on an individual farm basis; thus, the "farm-specific" replacement gilt program will maximizes the lifetime productivity of the female. Because a population of replacement gilts is managed under a common protocol, the age, body weight, backfat thickness, and estrous number at puberty are most likely confounded. In other words, age, body weight, backfat thickness, and estrous number are not mutually exclusive. Thus, a compromise has to be made between age, body weight, backfat thickness, and estrous number at time of mating. When using the same genetics and nutrition program, older gilts are generally heavier, have more backfat thickness, and have cycled more times than younger gilts.

Table 17: Effect of duration of boar exposure on puberty of gilts

Study & variables	Length of exposures & results				
Caton et al., 1986					
Season: Summer & Fall					
Length of exposure/day	5 min.	15 min.	30 min.	24 hrs	24 hrs
Type of boar contact	Full boar	Full boar	Full boar	Fenceline + 15 min Full boar	Fencelin e
Age of boar	6 months	6 months	6 months	6 months	6 months
Number of gilts	20	20	19	20	20
Age of gilt at start, days	180	180	180	180	180
Cycling by 210 days, %	40.0^{a}	35.0^{ab}	52.6^{a}	65.0^{a}	10.0^{b}
Interval to puberty, days	16.5	13.1	20.2	14.2	17.5
Avg age at puberty, days	194.9	192.1	198.5	194.0	199.0
Hemsworth et al., 1988					
Season: Not provided					
Length of exposure/day	0 min	5 min	15 min	24 hours	
Type of boar contact	None	Full boar	Fenceline	Full boar	
Age of boar	-	12+ mo.	12+ mo.	12+ months	
Number of gilts	16	15	16	16	
Age of gilt at start, days	176	176	176	176	
Detected in estrus, %	$31.3^{b,Y}$	$93.3^{a,X}$	$68.8^{a,XY}$	$81.3^{a,X}$	
Detected in estrus more than one day, %	40.0^{ab}	78.6^{a}	63.6^{ab}	38.5^{b}	
Avg age at puberty, days	203.4^{Y}	189.0^{X}	194.6^{XY}	188.0^{X}	
Paterson et al., 1989					
Season: Spring					
Length of exposure/day	0	2 min.	10 min.	30 min.	
Type of boar contact	None	Full boar	Full boar	Full boar	
Age of boar	-	18+ mo.	18+ mo.	18+ months	
Number of gilts	13	14	14	13	
Age of gilt at start, days	160	160	160	160	
Cycling by 240 days, %	46.2	100	71.4	92.3	
Interval to puberty, days	58.5^{a}	24.9^{b}	7.4^{c}	11.7^{c}	
Zimmerman et al., 1996					
Season: Winter					
Length of exposure/day	10 minutes	4 hours	10 min.	4 hours	
Type of boar contact	Full boar	Full boar	Fenceline	Fenceline	
Age of boar	8 months	8 months	8 months	8 months	
Number of gilts	14	14	14	14	
Age of gilt at start, days	172	172	172	172	
Cycling within 21 days	85.2%	92.1%	42.6%	54.1%	
Interval to puberty, days	13.6^{a}	13.4^{a}	25.7^{b}	24.0^{b}	
Avg age at puberty, days	186.9^{a}	187.0^{a}	199.4^{b}	198.3^{b}	

^{abc}Means within row with different superscripts differ (P< .05)
^{AB}Means within row with different superscripts differ (P< .02)
^{XY}Means within row with different superscripts differ (P< .01)

There is no doubt that the estrous number at first mating has an effect on number of piglets born live (**Tables 18** and **19**).[61-66] The increase in number of piglets born live at first farrowing for gilts bred at second estrous ranged from 0.4 to 1.3. Is the initial deficiency in number of piglets born from gilts bred at first estrus removed by the time the female is culled? A summary of the data in **Table 18** indicates that the number of piglets born live after three litters for gilts bred at second estrus is -0.3 to +2.0 piglets compared to gilts bred at first estrus (**Table 19**). The study by Young et al., (1990b) found that gilts bred at second estrus had an advantage of 1.3 pigs after four litters compared to gilts bred at first estrus.

Very few, if any, commercial farms collect estrous data on all their replacement gilts. Basically, most farms are organized to breed gilts during a specific age bracket. The assumption is that the gilts are bred at second or third estrus. The results of a recent survey in France on the affect of age of gilts at first farrowing on subsequent reproductive performance is indicated in **Table 20**.[67] The authors concluded that the optimal age at first conception depends highly on herd management. Mating of gilts early requires greater skill and care from the farmer than mating gilts at a later age. Based on their data, it appears that the age bracket to bred gilts is 220 to 250 days. A study of survey data in The Netherlands concluded that the optimal economic age at first conception is about 200 to 220 days.[68] However, most of the gilts in their data set were 200 to 280 days of age at conception. Hence, reliable conclusions can only be drawn from their data when age at first conception is anywhere between 200 and 280 days.

Table 18: Effect of estrous number at first mating on number of piglets born live

	Estrous number at mating		
Reference	**First**	**Second**	**Third**
Young et al., 1990a			
Age at mating, days	169.3	185.1	207.4
Backfat at mating, mm	19.0	21.6	23.3
Parity 1 – born live	9.1	9.5	8.9
Walker et al., 1989			
Age at mating, days	189	205	-
Backfat at mating, mm	17.1	18.9	-
Parity 1 – born live	9.4	10.0	-
Parity 2 – born live	10.3	10.5	-
Le Cozler, et al., 1999			
Age at mating, days	202	-	242
Backfat at mating, mm	16.7	-	17.9
Parity 1 – born live	9.4	-	10.0
Parity 2 – born live	9.5	-	10.1
Total piglets born live	18.9	-	20.1
MacPherson et al., 1977			
Age at mating, days	189	204	237
Backfat at mating, mm	Not reported	Not reported	Not reported
Parity 1 – born live	8.3	9.6	9.8
Parity 2 – born live	10.7	11.0	10.1
Parity 3 – born live	11.9	12.3	11.7
Rozeboom et al., 1996			
Age at mating, days	Not reported	Not reported	Not reported
Backfat at mating, mm	Not reported	Not reported	Not reported
Parity 1 – born live	9.1	10.0	8.8
Parity 2 – born live	8.7	8.8	10.4
Parity 3 – born live	11.3	10.5	9.4
Young et al., 1990b			
Age at mating, days	168.1	181.5	204.9
Backfat at mating, mm	19.6	21.8	24.0
Parity 1 – born live	9.0	9.7	8.8
Parity 2 – born live	9.3	9.1	9.1
Parity 3 – born live	9.8	9.8	10.4
Parity 4 – born live	9.7	10.5	10.5

Table 19: Summary for total number of piglets born live in **Table 18**

Parities	Estrous number at first mating			Difference	
	First estrus	Second estrus	Third estrus	Second - First	Third - First
P1+P2	19.7	20.5	--	+.80	--
P1+P2	18.9	--	20.1	--	+1.2
P1+P2	19.0	20.6	19.9	+1.6	+.90
P1+P2	17.8	18.8	19.2	+1.0	+1.4
P1+P2	18.3	18.8	17.9	+ 50	-.40
P1+P2+P3	30.9	32.9	31.6	+2.0	+1.6
P1+P2+P3	29.3	29.0	28.7	-.30	-.60
P1+P2+P3	28.1	28.6	28.3	+.50	+.20
P1+P2+P3+P4	37.8	39.1	38.8	+1.3	+1.0

Table 20: Effect of age of gilts at first farrowing on their subsequent reproductive performance

	Classes of age at first farrowing, days						
	<330	330-339	340-349	350-359	360-369	370 - 384	>384
Number sows	5176	5649	5582	5362	4502	4621	4739
Age at Ist farrowing, days	317[a]	334[b]	344[c]	355[d]	364[e]	376[f]	404[g]
Age at mating, d (gestation, 114 d)	203	220	230	241	250	262	290
Piglets born live per cull sow	53.78[a]	54.40[a]	54.11[a]	53.52[a]	53.27[a]	52.63[a]	50.93[b]
Pig/sow/yr	22.84[a]	23.14[b]	23.33[b]	23.36[b]	23.37[b]	23.67[c]	23.37[b]
Age at culling, d	988[a]	1007[ab]	1009[b]	1010[b]	1012[b]	1016[bc]	1026[c]
Parity at culling	5.04[a]	5.06[a]	5.02[a]	4.97[ab]	4.93[ab]	4.84[bd]	4.71[d]

[abcdefg]Means within a row with different letters differ (P<.05)

Backfat thickness and body fat have been shown to play a significant role in puberty attainment. A study in Australia selected gilts at 140 days of age and classified them as having low (0.39 to 0.47 in.), medium (0.51 to 0.59 in.) or high (0.63 to 0.71 in.) backfat thickness.[69] The proportion of gilts reaching puberty by 202 days of age was 100% for high, 92% for medium, and 67% for low. The number of estrous cycles from puberty to 202 days of age was 2.25 for high, 1.96 for medium, and 1.16 for low. The number of follicles at slaughter (202 days of age) was 18.25 for high, 19.08 for medium and 13.14 for low. Perhaps body fat at the time of selection (140 to 150 days of age) is more important than the amount of body fat at puberty!

Estrous detection procedure

Determination of first estrus in gilts is frequently difficult because many gilts do not show clear signs of estrus. Swedish research estimated that the heritability of estrus symptoms is 0.23 for proestrus, 0.16 for length of standing estrus, 0.29 for ability to show standing estrus, and 0.24 for intensity of vulva symptoms.[6] A study in The Netherlands found that 36% (242 or 680 gilts) of gilts show a questionable first estrus.[70] The increase in estrogen concentration during pro-estrus is responsible for the external signs of estrus, such as reddening and swelling of the vulva. A questionable estrus may be due to a lower systemic concentration of estradiol-17β. Research has found that the average concentration of estradiol-17β in serum is lower (P<.05) in gilts at first estrus compared to second and third estrus; plus, estradiol-17β is lower (P<.001) at second estrus than fourth estrus.[71,72] The duration of the reddening and swelling of the vulva is longer during the first and second estrus compared to later estrous periods (three to six estrous period). Although gilts with low backfat thickness (fed a high protein diet of 18.5% CP [0.96% lysine] from 55 to 198 lb. of body weight) had less intense and shorter reddening and swelling of the vulva at puberty than gilts with higher backfat thickness (fed a low protein diet of 13.1% CP [0.64%

lysine] from 55 to 198 lb. of body weight), there was no affect of backfat thickness on standing reflex or on the length of standing estrus at puberty.[73] Interestingly, the ability to exhibit the standing response and to ovulate within 10 days after weaning is heritable ($h^2 = 0.31$).[74] It has also been shown that gilts not exhibiting a solid standing reflex at puberty has a higher incidence of ovulation without a standing reflex within 10 days after weaning their first litter (21.4 vs. 6.2%, P<.001).

Because the standing response starts to diminish after 5 to 10 minutes of contact with a boar, cyclic gilts should not have continuous close contact with boars prior to estrous detection (**Table 21**).[75] This procedure will enhance the ability of the workers to accurately and efficiently detect estrous in replacement gilts.

Floor surface

The type of floor used during the rearing and development phase of gilts can affect the proportion of gilts selected for replacements. A number of pork producers have indicated that rearing gilts on a partial concrete floor is better than total slats. The major problem with total slats is feet and leg injuries.

Gilts per pen

Research is limited on how the of number of gilts per pen affect puberty attainment and cycling ability after reaching puberty. It appears that housing 10 to 30 gilts per pen should not hamper attainment of puberty. Groups greater than 50 to 60 per pen have shown delayed puberty when maintained in a relatively crowded condition throughout development. If gilts are housed in large groups, it is important to provide excellent boar contact.

Adequate research has not been conducted to determine whether the number of gilts per pen or square feet per gilt affects the ability of a gilt to express regular estrous cycles.

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Table 21: Proportion of gilts in standing estrus after initial boar exposure when heat-checking

Time of heat-checking	Minutes after initiation of estrous detection					
	0	5	10	11	16	21
AM Day 1	100%	100%	100%	92.3%	84.6%	84.6%
PM Day 1	100%	93.3%	93.3%	93.3%	86.7%	66.7%
AM Day 2	100%	94.1%	88.2%	82.4%	76.5%	70.6%
PM Day 2	100%	94.1%	76.5%	70.6%	64.6%	64.7%

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