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EC284

Pen-Mating Female Pigs: Problems and Possible Solutions

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Summary

The master control switch of a pork production enterprise is weaning day. Pork production managers have little or no control concerning when a weaned female will cycle or how long she will be in estrus after weaning. When females are pen-mated, the producer needs to use management procedures to: (1) prevent an excessive number of estrous females from expressing the standing response at the same time in the same pen, (2) ensure estrous females are bred at the proper time, (3) maintain an adequate level of fertility in boars, (4) evaluate boars for semen quality, (5) evaluate boars for level of sexual behavior and mating dexterity before and during the mating period, and (6) heat-check gestating females. Regardless of the boar-to-female ratio used or the management procedures implemented, there is no guarantee that all pen-mated females will be satisfactorily serviced during their first estrus after weaning. This publication discusses in detail the cause of problems that occur when pen-mating female pigs and provides possible solutions to the problems.

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Problem	Possible solutions
Low fertility of boars	The solutions generally recommended to enhance boar fertility are rotating boars for sexual rest and preventing heat-stress. Boars are easily trained to a ***daily rotation system*** by withholding feed until the boar has moved from a breeding pen to his home pen. Always feed a boar in his home pen before moving him to a breeding pen. Cool the boars by providing shade, a water sprinkler, and air movement. (See Section 4.2 on Page 14.)
Inadequate sexual behavior of boars	The main objective is to determine whether the boar is truly sexually inactive or has poor mating ability. Remove the boar from the breeding pen overnight. The next morning take the boar to a breeding pen that has estrous sows. Observe the boar for his ability to pursue and mount a female, obtain an erection, gain entry into the vagina, and successfully copulate for more than two minutes. (See Section 4.3 on Page 15.)
Multi-sire competition	Excessive fighting among boars can be a problem. The only method to prevent fighting is to house the boars individually and rotate them on a schedule either into or out of the breeding pen. (See Sections 3.8 on Page 10 and 4.3.1 on Page 15.)
Low number of successful matings per number of mounts by boar	Make sure the boar is not too large or too small for the group of sows being mated. To prevent interrupted matings by another boar, only have one boar in the breeding pen. Evaluate the boar for his ability to successfully copulate. (See Sections 3.3 on Page 7 and 4.3 on Page 15.)
Inadequate number of working boars	Having more boars available at the time when groups of females are in estrus increases the chance that a sow in heat will have a satisfactory mating, and increases the chance of her becoming pregnant. The factors to consider are: (1) how many females are being weaned; (2) how many pens are being used for breeding; (3) how many weaned females are being placed in each breeding pen; (4) are boars going to be sexually rested; (5) how much time are the boars given for sexual rest; and (6) what percentage of weaned females is first found in estrus on each day of the breeding period. (See Section 4.8 on Page 17.)
Too many sows in estrus on same day	One way to reduce the excessive number of estrous females accumulating when pen-mating is to use two, three, or four breeding pens or wean sub-groups (split-wean) every two to three days into two, three, or four breeding pens. Another solution for getting all the sows mated is to use hand-mating in combination with artificial insemination. (See Section 4.1 on Page 11.)
Sows mated at improper time	Although sows should be mated twice at 10 to 44 hours after the onset of estrus, there is no way to guarantee that sows will be mated twice when pen-mating. Rotating boars every 12 hours might help estrous sows to get mated twice. (See Section 3.4 on Page 9.)
Estrous sows not getting mated	Make sure there are an adequate number of working boars. Use a boar rotation system. (See Sections 3.5 on Page 9 and 4.2 on Page 14.)
Sows getting injured	Reducing the number of females injured due to excessive sexual behavior by boars can be accomplished by not placing multiple boars in the breeding pen until the afternoon of the fourth day after weaning. This practice increases the number of estrous females available for boars to court and mate. (See Section 3.7 on Page 10.)
Inadequate production records	Good records can show you if there is potential income available for increased level of management at breeding time (4 to 10 days post weaning). Producers that keep records calculate the value of an extra pig by subtracting the cash cost from the market value. In a typical year, this value is roughly $65 per pig or around $500/litter. (See Section 4.9 on Page 18.)

Too many nonproductive sow days	A nonproductive sow day is defined as any day a female in the breeding herd is not gestating or nursing a litter. The best solution to reduce nonproductive sow days is to check bred sows for return to estrus. The majority of bred sows returning to estrus should occur on days 25 to 36 after weaning (18 to 35 days after mating). The key point to remember: do not let females receive boar stimuli (sight, sound, or smell) for one hour before checking for estrus. (See Section 4.6 on Page 16.)
Excessive physical and environmental stress	All types of physical (i.e. fighting) and environmental (i.e. extreme hot or cold weather) stress should be minimized for 28 days after mating. (See Section 4.7 on Page 17.)
Inadequate pen-mating facility design	There are numerous factors to consider when designing and managing an outdoor or indoor pen-mating facility. Make sure the facility can be easily managed to enhance reproductive performance. (See Sections 5.0 on Page 19 and 6.0 on Page 21).

2. Introduction

Pen-mating, one of three mating systems available to pork producers, (Table 1) is the process of putting boars and females in the same pen for a designated period (usually 21 to 42 days) using an unsupervised mating process. Scientific experiments have evaluated the influence of pen-mating on reproductive performance. Although pen-mating is utilized as a labor-saving strategy for breeding management, farrowing rate (number of females farrowed per number of females exposed) of females pen-mated at first estrus after weaning varies substantially (Table 2). A comparison between breeding pens in Table 2 cannot be made because of differences in the age of boars, number of boars per pen, and number of sows in each pen.

It is important to have a high farrowing rate because farrowing rate is significantly correlated with the number of live pigs born per bred female per year. An analysis of hand-mating data from North Carolina State University's Swine Development Center found that the number of live pigs born per litter increased by 0.5 piglets per each 10 percent increase in farrowing rate (Figure 1). An analysis of hand-mating data gathered in England found that the number of live piglets born per litter increased by 1.3 piglets per each 10 percent increase in farrowing rate. Many times, a decrease in farrowing rate and/or litter size born live occurs because various biological and sociological events in the pen-mating environment cannot be adequately controlled or managed.

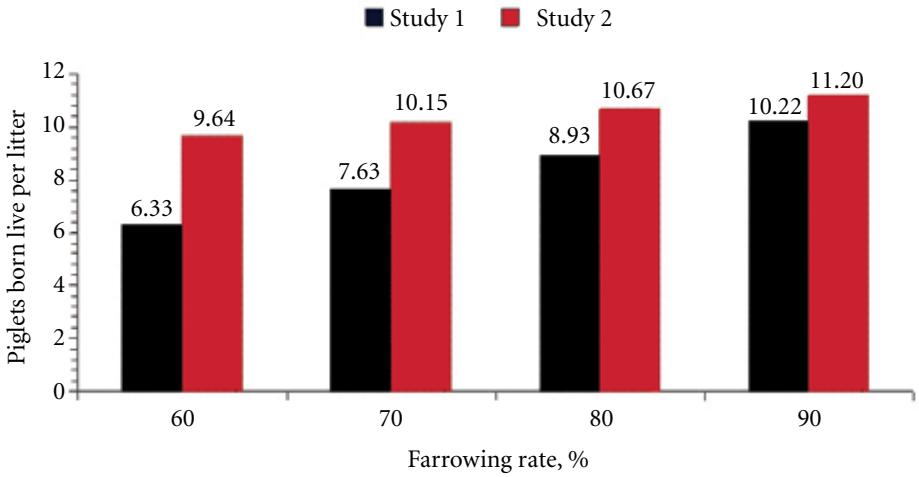

Figure 1. Relationship between farrowing rate and live piglets born per litter (data from Rasbech, 1969; North Carolina State University Swine Development Center Reports, 1972-1976).

While it is recommended that pork producers use hand-mating and/or artificial insemination, we recognize that some producers elect to use pen-mating. A survey conducted by the United States Department of Agriculture during 2006 found that 62.5 percent of sows and 75.4 percent of gilts were pen-mated on farms with fewer than 250 sows (Table 3). This publication discusses various pen-mating issues and their possible solutions.

3. Common pen-mating issues

To ensure the best results from pen-mating, it is important to understand the biology and behavior of boars and sows while they are involved in a pen-mating system. The key issues are:

- Accumulation of estrous females
- Boar fertility
- Boar mounting efficiency
- Inadequate sexual behavior of boars
- Improper time mated
- Females not being mated
- Injured females
- Multi-sire competition for a sexual partner

Table 1. Comparison of mating systems for swine.

Mating System	Description	Advantages	Disadvantages	Comments
Pen-mating	Boars and females housed together continually during the breeding period	• Lowest labor requirements • Simplistic facility design • No heat checking skill needed	• Requires most boar power for satisfactory fertility • No control over boar usage • Individual breeding records not available • Most variability in farrowing rate and litter size	Not recommended for high investment, high intensity operations, or where financial stability and security is necessary
Hand-mating	Boars housed separately from females and brought together during estrus detection and mating only	• Controlled mating • Can single out bad boars • Requires less boar power • Helps prevent injuries • Farrowing dates can be recorded • Induced farrowing possible	• More labor intensive than pen-mating • Requires more breeding pens and/or boar pens • Heat checking skill required	A properly designed facility will improve labor efficiency
Artificial Insemination	Semen is collected from boars, diluted, and placed into female's reproductive tract.	• Controlled mating • Requires least boar power • Farrowing dates can be recorded • Induced farrowing possible • Lowest cost per ejaculate • Best disease control • Gilts can be mated to older, heavier boars • Best use of superior boars	• More labor intensive than pen-mating • Highest level of management required • Heat checking skill required • Possible reduced farrowing rate and litter size vs. hand mating if not performed properly	• Used on over 80 percent of the females in the U.S. • No guarantee to be disease free • It is possible to develop a closed herd

Table 2. Farrowing rate of sows from first estrus after weaning when pen-mating on a commercial farm in Nebraska (D. G. Levis, unpublished data).[a]

	Pen One Two Duroc Boars (Mature age)			**Pen Two** Two Crosbred Boars (Young age)			**Pen Three** Three Crossbred Boars (Mature age)		
Date	Number of Females		FR[d]	Number of Females		FR	Number of Females		FR
Weaned	W[b]	F[c]	(%)	W	F	(%)	W	F	(%)
Sep 30	8	5	62.5	7	4	57.1	7	5	71.4
Nov 6	9	4	44.4	6	5	83.3	6	4	66.7
Dec 12	7	3	42.9	6	5	83.3	4	2	50.0
Jan 18	6	4	66.7	5	3	60.0	4	4	100.0
Feb 23	8	4	50.0	5	3	60.0	6	5	83.3
Apr 1	6	5	83.3	6	4	66.7	8	4	50.0
May 7	8	7	87.5	5	3	60.0	7	5	71.4
Jun 13	6	5	83.3	7	6	85.7	5	4	80.0
Jul 19	9	3	33.3	6	4	66.7	7	4	57.1
Aug 21	7	4	57.1	5	2	40.0	5	3	60.0
Totals	74	44	**59.5**	58	39	**67.2**	59	40	**67.8**

[a]All females were weaned into a boar pen and remained in the pen with the boar until farrowing.
[b]W is weaned
[c]F is farrowed
[d]FR is farrowing rate

- Inadequate production records to use to make appropriate decisions

3.1. Accumulation of estrous females

The best method available to shorten the duration of time spent breeding sows is batch weaning, which can be thought of as the "master control switch" for a swine operation. However, weaning all sows on the same day can result in several sows being in estrus on the same day. After a group of females is weaned, management has essentially no control over the cycling pattern of the female group. Currently, there is no U.S. Food and Drug Administration approved product to control estrus in weaned sows. The following three factors have major influence on the number of females in estrus on each day after weaning: (1) the number of sows weaned and placed in one breeding pen on the same day, (2) the total number of sows coming into estrus on each day after weaning (weaning-to-estrus interval), and (3) the duration of estrus for each sow. Duration of estrus is the number of hours each estrous female is receptive to boar stimuli. These three factors cause estrous sows to accumulate on various days/hours after weaning (Figure 2).

3.1.1. Weaning-to-estrus interval. The majority of recently weaned females should cycle four to seven days after weaning (Figure 3); however, the distribution of females first detected in estrus on each day after weaning can be quite variable (Figure 4). The following can influence the weaning-to-estrus interval: genetics, parity, amount of feed consumed during lactation, season, length of lactation, suckling frequency of piglets, photoperiod, ambient temperature, body condition at weaning, and mycotoxins in the feed. As the weaning-to-estrus interval increases from three to five days, the average duration of estrus decreases (Figure 5).

3.1.2. Duration of estrus. Table 4 indicates that a substantial amount

Table 3. Percentage of sows and gilts pen-mated according to number of sows and gilts on inventory (USDA, 2007).

	Number of sows and gilts on inventory of pork enterprise		
Item	Less than 250	250 to 499	500 or more
Sows	62.5	23.4	1.9
Gilts	75.4	43.1	4.2

Table 4. Variation in duration of estrus (Steverink et al., 1999).

	First estrus after weaning, hrs		Repeat-breeder, hrs	
Item	Average	Range	Average	Range
Sows	50.1	32 to 69	47.5	30 to 69
Gilts	41.2	19 to 52	40.0	12 to 82

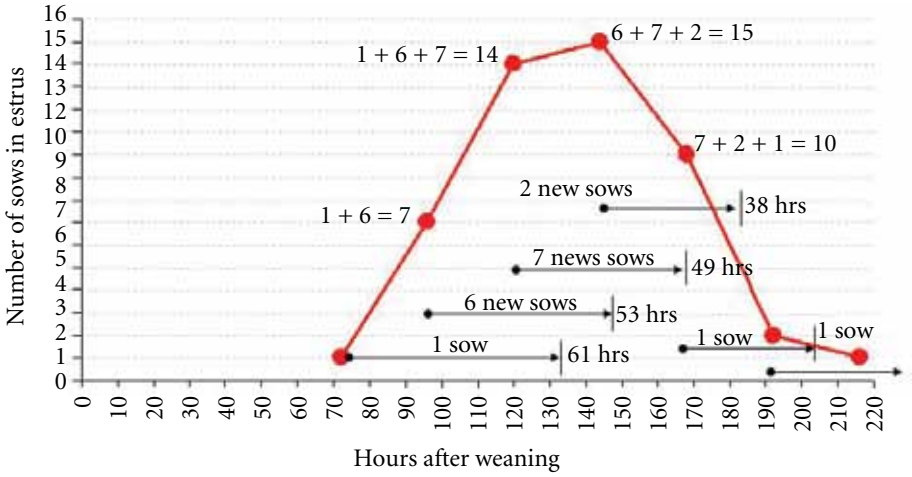

Figure 2. Estimated number of females in estrus on each day when pen-mated in one breeding pen. Twenty females are weaned the same day and 90 percent cycle within eight days after weaning.

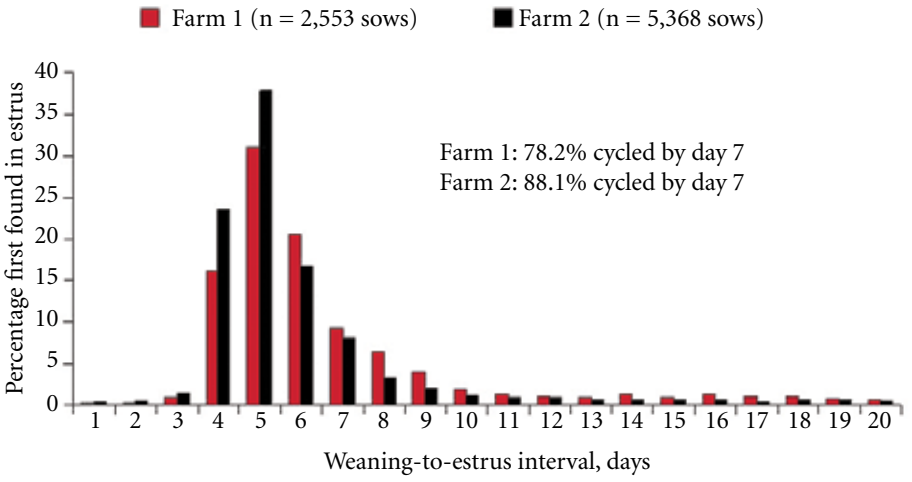

Figure 3. Distribution of females first detected in estrus by day after weaning (D. G. Levis, unpublished data).

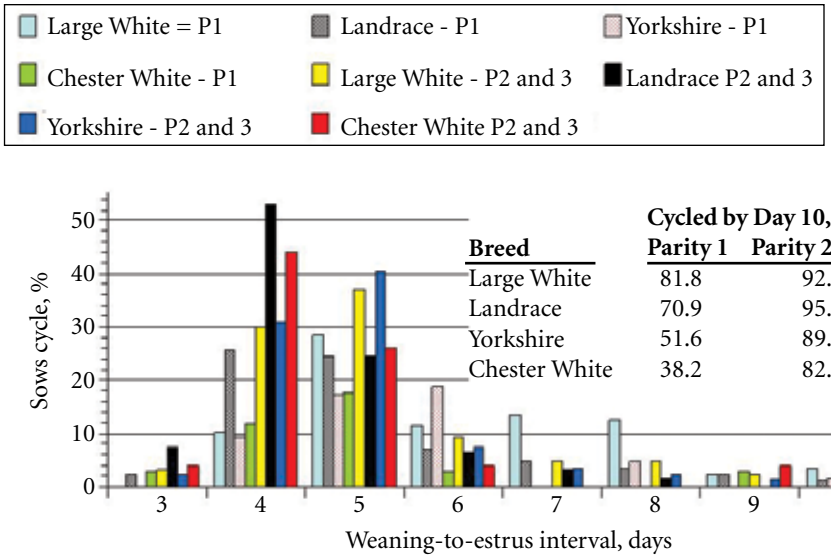

Figure 4. Influence of genetics and parity on weaning-to-estrus interval (Maurer et al., 1985).

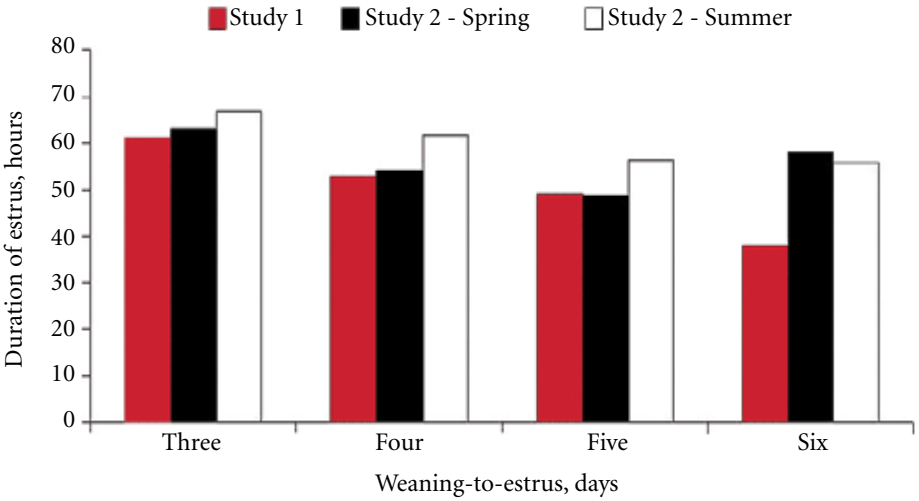

Figure 5. Relationship between weaning-to-estrus interval and duration of estrus (Kemp and Soede, 1996; Belstra et al., 2002).

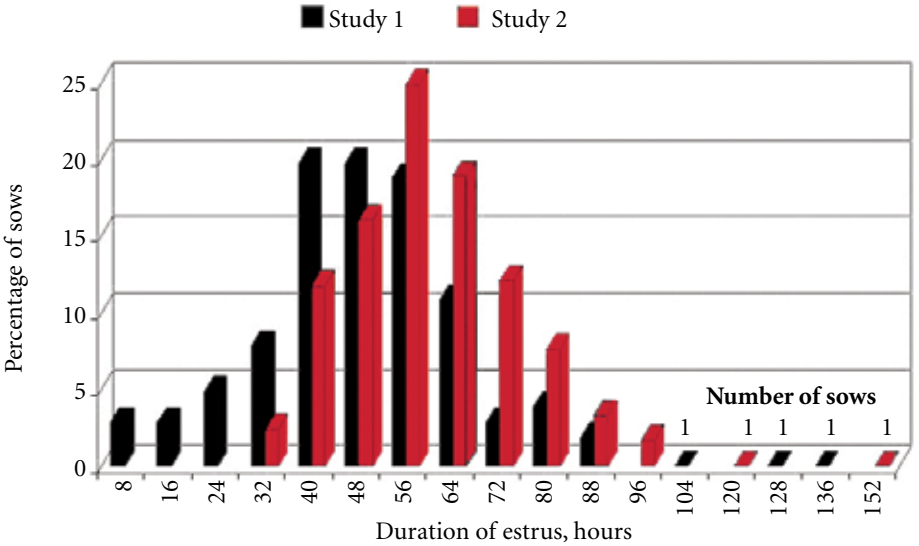

Figure 6. Frequency distribution for duration of estrus (W-Y Huang et al., 1991; K. F. Weitze et al., 1994).

of variation occurs in the duration of estrus. Figure 6 depicts the frequency distribution for the percentage of females standing for 8 to 152 hours. Although the weaning-to-estrus interval influences the duration of estrus, there is a substantial amount of variation in the duration of estrus within a specific weaning-to-estrus interval (Figure 7). In Figure 7 the duration of estrus ranged from 24 hours to 72 hours for a group of sows with a weaning-to-estrus interval of 4.5 days.

3.1.3. Time from onset of estrus to ovulation. Research has shown that as the weaning-to-estrus interval increases, the duration of estrus decreases and the time from onset of estrus to ovulation decreases. However, a substantial amount of variation occurs in the time of ovulation after onset of estrus within a specific duration of estrus. As indicated in Figure 8, the time of ovulation after onset of estrus ranged from 22 hours to 46 hours for a group of sows, with duration of estrus of 56 hours. ***Optimal fertilization of ova results when females are mated 0 to 24 hours before ovulation.*** When females are mated outside this range, as can easily occur when pen-mating females, the fertilization rate of the ova decreases, thus reducing litter size.

By combining the weaning-to-estrus interval with the duration of estrus effects, it is easy to see how in pen-mating situations the number of females in estrus accumulates daily during the breeding period. Figure 2 illustrates how the number of females in estrus accumulates on each day when 20 females are weaned on the same day and placed in one breeding pen. ***It is possible to have 75 percent of the weaned females in estrus on day six after weaning.*** Although this pattern varies between each group weaned and between farms, the principles shown can be applied to any weaning system to estimate the number of females in estrus on each day.

3.2. Boar fertility

When the number of estrous females accumulates as shown in Figure 2, overworked boars may result in a boar fertility problem. Some overworked boars have a decrease in sexual behavior and do not breed very many different females. Another possibility is that an aggressive boar may continue to breed females after his sperm supply is substantially reduced or depleted.

Boars need sexual rest for sperm replenishment because sperm output decreases rapidly. A research study indicated that after five days of sexual rest and the boars were collected every 24 hours (Figure 9):

- The second ejaculation contained 46.9 percent fewer sperm cells than the first ejaculation.
- The third ejaculation contained 51.7 percent fewer sperm cells than the first ejaculation.
- The fourth ejaculation contained 55.8 percent fewer sperm cells than the first ejaculation.
- The fifth ejaculation contained 67.9 percent fewer sperm cells than the first ejaculation.
- The sixth ejaculation contained 80.2 percent fewer sperm than the first ejaculation.

Generally, when on a 12- or 24-hour mating interval, the sperm output number tends to stabilize after five matings. The important question is, "What level of sperm output is being reached at stabilization — fertile, subfertile, or infertile?" It is believed 3 to 6 billion motile sperm are needed to adequately fertilize ova. However, the number of motile sperm required for good fertility varies from boar to boar.

The major problem with pen-mating is that boars do not pace themselves to mate females on a 12- to 24-hour interval. For example, an aggressive boar may mate the first estrus female five times during the first 24 hours he is in the weaned female pen. Obviously, a boar that has mated

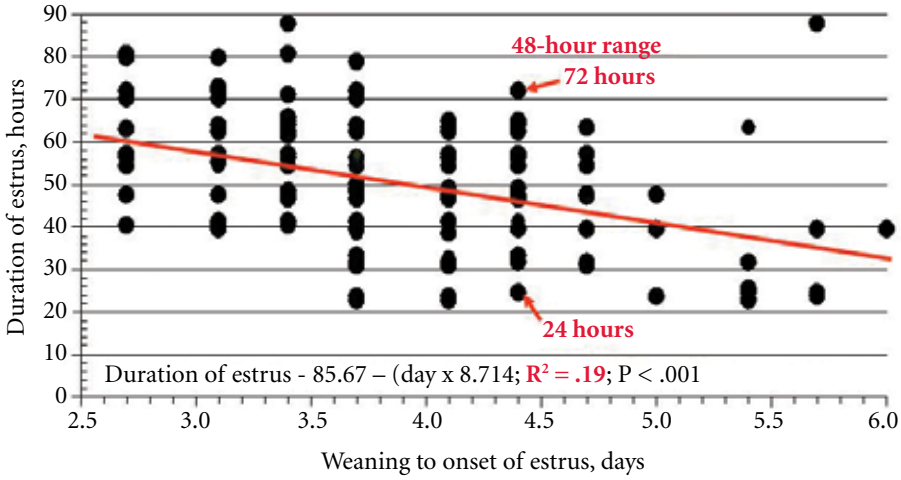

Figure 7. Variation in duration of estrus within and among weaning-to-estrus intervals (Kemp and Soede, 1996).

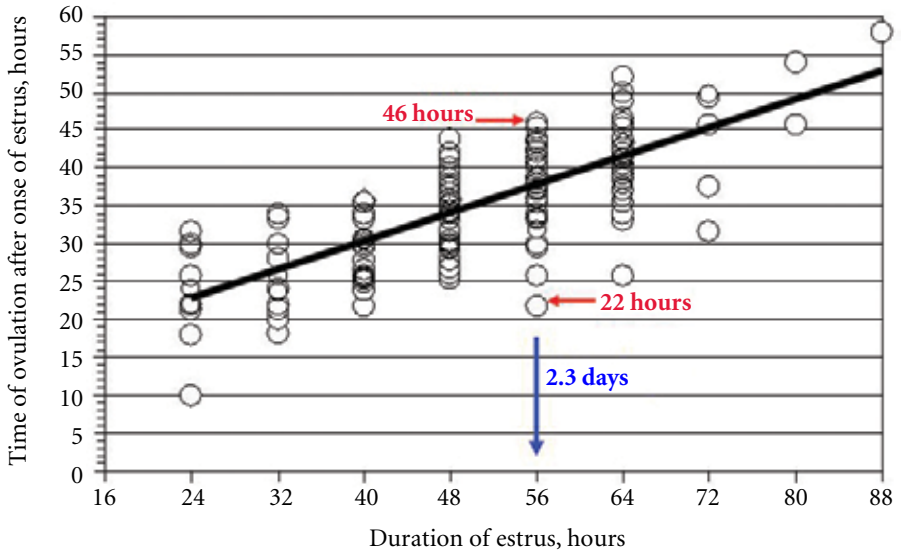

Figure 8. Variation in time of ovulation according to duration of estrus in multiparous sows (Soede et al., 1995).

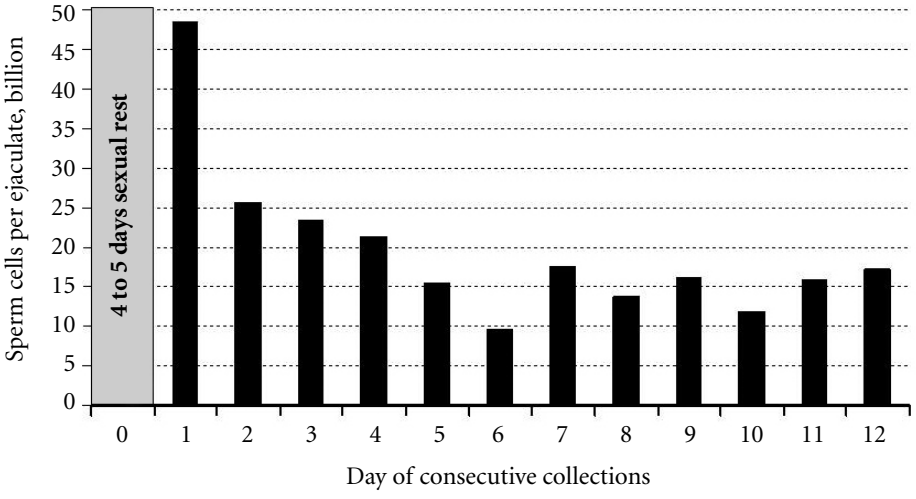

Figure 9. The effect of boars (14 months of age) ejaculating every 24 hours on sperm output (modified from Johnson et al., 1969).

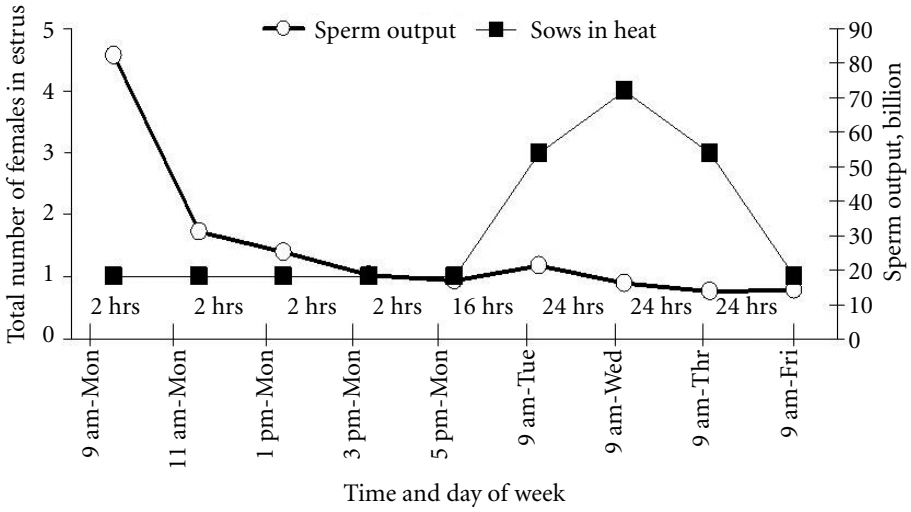

Figure 10. Relationship between sperm output and accumulation of estrous females when pen-mating in one breeding pen. Four females are all weaned on the same day and housed continuously with the same boar (sperm output data modified from Cameron, 1985a).

Table 5. Fertility of sows after a natural mating by boars ejaculating either one or four times per day (Paquignon et al., 1984; Nowak et al., 1988).

	One ejaculation per day			Four ejaculations per day		
Item	Sows mated 1st day of ejaculation frequency	Sows mated 4th day of ejaculation frequency	Total or Average	Sows mated 4th day of ejaculation frequency	Sows mated 5th day of ejaculation frequency	Total or Average
Number sows	6	6	12	6	6	12
Pregnancy rate, %	83.3	100.0	91.6	50.0	66.6	58.3
Embryonic survival, %	71.6	67.3	69.2	79.5	79.1	79.2

five times the first day will have a substantial reduction in sperm count for the remaining females he will mate (Figure 10). The pen-mating example indicated in Figure 10 weans four females on the same day and houses the females with one boar that is not rotated for sexual rest. It is assumed that onset of estrus occurs on Monday (one female), Tuesday (two females), and Wednesday (one female) after being weaned the previous Thursday. The assumed duration of estrus is the same as indicated in Study 1 of Figure 5. If the boar only mates once every 24 hours after the first five matings, there is a risk that some females will: (1) not be mated because there is more than one female in estrus on Tuesday, Wednesday, and Thursday, (2) only be mated once, (3) be mated at the wrong time with respect to time of ovulation, especially, if only mated once, and (4) be mated more frequently than other females.

If the boar maintains a high level of sexual activity and mates estrous females numerous times, his fertility will be substantially diminished. The effect of boars mating too frequently on decreasing farrowing rate was clearly demonstrated by scientists in France. The researchers controlled the mating frequency by using hand-mating. Boars that only mated once per day had a higher pregnancy rate compared to boars that mated four times per day (Table 5). Mating frequency did not influence embryonic survival. It did influence the mating behavior of six boars (10 months of age at start of experiment) during five consecutive days on each ejaculation frequency of one, two, three, or four times per day:

- 100.0 percent ejaculated at a frequency of one time per day,
- 91.6 percent ejaculated at a frequency of two times per day,
- 58.3 percent ejaculated at a frequency of three times per day, and
- 41.5 percent ejaculated at a frequency of four times per day.

An ejaculation frequency of two times per day (12-hour interval) for four days has resulted in defective sperm maturation and abnormal development of sperm motility.

3.3. Boar mounting efficiency and quality of mating

When pen-mating, the number of successful matings is very low when compared to the large number of mounts performed by a boar. The number of mounts, number of matings, number of mounts per mating, and mating efficiency (number of matings divided by number of mounts times 100) observed in one pen-mating study is shown in Table 6.

Each mating pen contained between two and four one-year-old boars and four estrous females. The boars in each breeding pen were full siblings from the same litter and had been reared and used for natural mating together. Mating efficiency ranged from 1.4 percent (two matings per 138 mounts) to 57.1 percent (four matings per seven mounts). Mating efficiency is substantially reduced when large differences exist in body size between a boar and female. Two females (12 and 15) were mounted 72 and 59 times, respectively, but they were never mated by any boar in the pen (Table 7). These

two females were 139 and 86 pounds heavier than the average body weight of the boars in the pen. These results show that despite the low number of females to boars in each of the pens, there is no guarantee that each estrous female in a pen-mating situation will be mated satisfactorily.

Researchers in England investigated the reproductive behavior of 80 gilts and 14 boars when mating occurred in a dynamic mating system. Each mating pen contained four to five boars and 20 gilts. The two mating pens were 59 feet x 33 feet. Half of the pen was deep straw and the other half was a dunging and feeding area. Each week the four oldest gilts were removed from each pen and replaced by four new gilts. The overall quality of each observed mating activity (MA) was scored according to the following quantitative behavioral criteria: (1) the total time [minutes] that a boar spent on the gilt's back [TTGB], (2) number of successful mounts that lasted at least 10 seconds on the gilt's back [SM], (3) the mounting efficiency [(SM/AM) x100], and (4) the ratio TTGB/SM.

According to these criteria, the observed MA were classified as very poor, poor, fair, good, or very good (Table 8). Of the 933 mating activities observed in the study, 59 percent of the matings were classified as poor and very poor (Table 8). The reasons for termination of matings were interruptions by another boar (29 percent), gilt lying down (27 percent), gilt moving away (18 percent), boar dismounting (17 percent) and interruptions by another gilt (1 percent). Gilts were kept with the boars for about 33 days and pregnancy was diagnosed using ultrasonic scanning at time of removal from pen. Of the 80 gilts, 84 percent had a positive pregnancy diagnosis. Gilts with a positive pregnancy diagnosis had received more total mating activity and more total good + very good mating scores.

Table 6. The number of mounts, number of matings, number of mounts per mating, and mating efficiency when pen-mating four females per pen (Tanida et al., 1989).

Observation Period	Mating pen number	Boar Identification[b]	Sexual activity[a]			
			Number of mounts	Number of matings	Mounts per mating	Mating efficiency, %[c]
July 8 to July 11	1 (4 sows)	LW1	58	2	29.0	3.4
		LW2	61	5	12.2	8.2
		LW3	35	7	5.0	20.0
		LW4	39	7	5.6	17.9
	2 (4 sows)	H1	7	4	1.8	57.1
		H2	14	1	14.0	7.1
July 28 to July 31	1 (4 sows)	D1	20	2	10.0	10.0
		D2	88	4	22.0	4.5
		D3	138	2	69.0	1.4
	2 (4 sows)	LR1	51	3	17.0	5.9
		LR2	87	4	21.8	4.6
		LR3	54	4	13.5	7.4
		LR4	37	2	18.5	5.4

[a]Mating behavior was observed for 72 continuous hours.
[b]LW is Large White; H is Hampshire; LR is Landrace; D is Duroc.
[c]Number of matings divided by number of mounts x 100.

Table 7. The number of mounts, number of matings received per female, mating efficiency, and proportion of females mated during a 72-hour period of pen-mating (Tanida et al., 1989).

Observation Period	Mating Pen Number	Female Identification[a]	Sexual activity			
			Number of Mounts	Number of matings	Mating efficiency, %[b]	Proportion of females mated
July 8 to July 11	1 (4 boars)	1	61	3	4.9	
		2	30	62	0.0	
		3	75	8	10.7	100.0%
		4	27	4	14.8	(4 of 4)
	2 (2 boars)	5	0	0	0	
		6	1	0	0	
		7	8	3	37.5	50.0%
		8	12	2	16.7	(2 of 4)
July 28 to July 31	1 (3 boars)	9	46	2	4.3	
		10	65	4	6.2	
		11	63	2	3.2	75.0%
		12	72	0	0	(3 of 4)
	2 (4 boars)	13	57	7	12.2	
		14	79	4	5.1	
		15	59	0	0	75.0%
		16	34	2	5.9	(3 of 4)

[a]All sixteen females were in estrus. [b]Number of matings divided by number of mounts x 100.

Table 8. Percentage of gilt matings that were scored as very poor, poor, fair, good, or very good (Grigoriadis et al., 2000).

Mating score criteria	Very poor	Poor	Fair	Good	Very good
TTGB, min[a]	< 1	1 to 2	2 to 3	3 to 5	>5
SM/AM, %[b]	< 50	50 to 75	50 to 75	> 75	> 75
TTGB/SM	< 1	<1	1 to 3	1 to 3	> 3
Percent of gilt matings (933 mating events)	35	24	14	18	9

[a]Total time the boar spent on the gilt's back
[b]Mounting efficiency = number of successful mounts (SM)/number of attempted mounts (AM) x 100

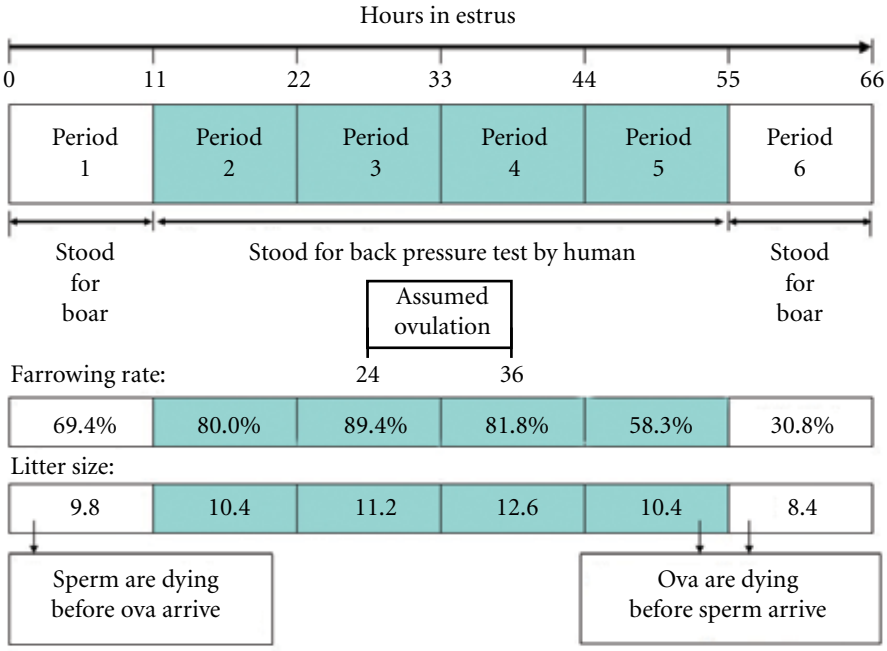

Figure 11. Relationship between time of a single natural mating and reproductive rate in gilts (modified from Willemse and Boender, 1967).

Table 9. Influence of number of natural matings (single or double) on farrowing rate and number of piglets born live per litter (Walker and Bilkei, 2002).

	Farrrowing rate, %		Piglets born live/litter		Fecundity index [1]	
Farm	Single	Double	Single	Double	Single	Double
1	86.0	86.9	9.3	10.0	800	869
2	91.3	92.0	9.6	10.2	876	938
3	91.3	92.0	9.6	10.3	876	948

[1]Fecundity index = (Farrowing rate x litter size) x 100

Table 10. Number of matings per boar and number of different estrous females mated by each boar during pen-mating (Levis et al., 1997).[a]

Boar identification	Number of times boar mated	Number of females mated	Number of females in estrus	Females mated (%)
A	9	2	2	100
B	4	1	2	50
C	5	1	2	50
D	4	2	2	100
E	1	1	2	50
F	5	1	2	50
G	0	0	2	0
H	7	2	2	100
I	5	1	2	50
Total or Avg	40	11	18	**61.1**

[a]The boar was placed in a pen that contained two females in estrus and one female not in estrus for 4.7 days.

3.4. Improper time mated

Figure 11 shows that for optimum farrowing rate and litter size, gilts should be bred 11 to 44 hours after standing estrus starts. When too many estrous females are in the same pen, they may be bred only one time or not at all. It is very possible that a single mating may occur too early or too late during estrus. When gilts or sows are only bred once at 0 to 11 hours after onset of estrus, a lower conception rate and litter size occurs because sperm cells start to die before ovulation takes place. When gilts or sows are only bred once sometime between 44 and 66 hours after onset of estrus, pregnancy rate and litter size can sharply decrease because ova have died before the arrival of sperm cells or polyspermy (more than one sperm fertilized the ova) occurs, which results in cellular problems in the development of fertilized ova. ***In pen-mating situations, there is no control over mating time.***

It is important that sows and gilts are mated multiple times. Optimal fertility occurs when an adequate number of viable spermatozoa are present in the oviduct just prior to ovulation. The influence of natural mating frequency on farrowing rate and number of piglets born live per litter from outdoor breeding units is indicated in Table 9. Farrowing rate did not differ between single- and double-mated sows; however, the number of live-born piglets per litter was significantly greater for sows receiving two matings compared to sows receiving one mating.

3.5. Females not being mated

In pen-mating situations some females are never mated even though they are in estrus. This was demonstrated in one study where two to four boars were placed in a breeding pen with four estrous females. The overall percentage of females mated was 75 percent (12 of 16 females), with the number of matings per female ranging

from zero to eight (Table 7). Mating efficiency ranged from 0 to 37.5 percent (three matings per eight mounts).

Some pork producers have tried to improve results from pen-mating by putting one boar in a pen with two weaned females. However, the farrowing rate (calculated on the first service after weaning) achieved with this method rarely exceeds 70 to 75 percent. Results from a research trial in which one boar was placed in a pen with three females (two estrous females, one anestrous female) showed the overall percentage of females mated was 61.1 percent (Table 10). Only three of the nine boars (33 percent), each of which were known to have a moderate to high level of sexual behavior, mated both females that were in estrus in their pen. The other six boars also mated females but they mated the same female many times. Other research also has shown some boars select a particular female with whom they spend a preponderance of courtship time. ***It appears there is no simple way to pen-mate females to be absolutely sure all females are bred during the same estrous period***.

3.6. Inadequate sexual behavior of boars

Inadequate sex drive in boars, such as lack of willingness or eagerness to pursue, mount, and attempt service of females when pen-mating, can be influenced by high environmental temperatures, domination by other boars or larger females, bad past breeding experiences (psychological), over-use (sexual fatigue), sickness, inexperience, immaturity, excessive body condition, and old age.

3.7. "Injured" females

Pen-mating can result in estrous females getting injured because too many boars are in the pen when the first female stands for mating. Being mounted excessively increases the risk that females will experience muscle tears, fractures, or spinal cord injuries.

Table 11. Frequency distribution for the total number of copulations (all durations of time) per sow and number of copulations lasting longer than two minutes per sow in a multisire mating pen (Kongsted and Hermansen, 2008).[a]

	Number of sows			Number of sows	
Total number of copulations per sow	All durations of time copulating	Copulations lasting two or more minutes	Total number of copulations per sow	All durations of time copulating	Copulations lasting two or more minutes
0	13[b]	18[c]	7	5	0
1	5	11	8	2	0
2	2	5	9	1	0
3	5	10	10	2	1
4	4	1	12	2	0
5	2	1	17	1	0
6	2	0	19	1	0

[a]Number of sows in each group varied from five to nine and the boar to sow ratio ranged from 1:3 to 1:1 on observations days of three to seven after weaning. A total of 47 sows were observed.
[b]Three of the 13 sows not mated had shown signs of estrus. Ten sows did not express estrus.
[c]Although 18 sows had shown signs of estrus, they had no copulations lasting two minutes or more.

Table 12. Frequency distribution for the total number of copulations (all durations of time) per boar and number of copulations lasting more than two minutes per boar in a multisire mating pen (Kongsted and Hermansen, 2008).[a]

	Number of boars			Number of boars	
Total number of copulations per boar	All durations of time copulating	Copulations lasting two or more minutes	Total number of copulations per boar	All durations of time copulating	Copulations lasting two or more minutes
0	2	8	8	1	0
1	3	5	9	1	0
2	2	6	10	1	0
3	3	7	11	2	0
4	5	1	12	3	0
5	1	1	13	2	0
6	1	2	14	2	0
7	2	1			

[a]Number of sows in each group varied from five to nine and the boar to sow ratio ranged from 1:3 to 1:1 on observations days of three to seven after weaning. A total of 31 boars were observed.

3.8. Multi-sire competition for sexual partner

In a multi-sire mating system the sows are placed in either large indoor or outdoor breeding pens at weaning with a group of boars. Reproductive performance in a multi-sire mating system depends to a large degree on appropriate mating behavior of the sows and boars. The duration of ejaculation in the boar varies from 3 to 20 minutes. The ejaculation process of a boar occurs in four phases: First phase — pre-sperm (clear fluid); Second phase — sperm-rich (contains 80 percent of total sperm cells ejaculated); Third phase — sperm-poor (mainly consists of fluids from the vascular glands), and Fourth phase — gelatinous plug. Approximately 80 percent of the total number of sperm cells ejaculated during mating occurs within the first 1.5 to 2.0 minutes of copulation. Thus, the boar should mate the female for at least two minutes to increase the chances that the sperm-rich fraction has been deposited into the sow's reproductive tract.

Table 13. Percentage of copulations interrupted, percentage of sows showing estrus, and percentage of sows diagnosed pregnant (Kongsted and Hermansen, 2008).

Item	Pens with large sows	Pens with small sows	Total or average
Number of sows	25	22	47
Percentage of all copulations interrupted			
Another boar	32	45	
Another sow	3	3	
Sow collapses	7	12	
Sow walks away	14	12	
Total	56	72	
Number of sows scanned for pregnancy[a]	23	21	44
Percentage of sows exhibiting estrus within seven days after weaning			
Average of all sows	76	82	79 (37 sows)
Minimum among pens	67	43	
Maximum among pens	100	100	
Percentage of estrous sows found pregnant at four weeks after weaning			
Average of all sows	76	65	71 (24 sows)
Minimum among pens	25	50	
Maximum among pens	100	78	
Percentage of all weaned sows found pregnant at four weeks after weaning			
Average of all sows	57	52	55 (24 of 44)
Minimum among pens	17	17	
Maximum among pens	100	28	

[a]One sow was culled before pregnancy diagnosis and two sows were impossible to diagnose.

When a group of sows are being mated with a group of boars (multi-sire mating system), a specific copulation can be interrupted by another boar or another sow, or the sow collapses due to the weight of the boar; thus, the duration of copulation can be less than two minutes. The frequency distribution for the total number of copulations and number of copulations lasting more than two minutes per sow in a multi-sire mating pen experiment in Denmark is indicated in Table 11. Eighteen of 47 sows (38.3 percent) did not receive a copulation lasting more than two minutes. Three of the 13 sows not mated had shown signs of estrus. Eleven of 47 sows (23.4 percent) received one mating lasting more than two minutes. The frequency distribution for the total number of copulations and number of copulations lasting more than two minutes per boar in a multi-sire mating pen is indicated in Table 12. Two boars had no copulations. Eight of 31 boars (25.8 percent) had no matings lasting for two minutes or more. The percentage of copulations interrupted, percentage of sows showing estrus, and percentage of sows diagnosed pregnant is indicated in Table 13. The percentage of all copulations interrupted was 56 percent for pens with large sows and 72 percent for pens with small sows. The majority of the interruptions were due to another boar. The percentage of all weaned sows found pregnant at four weeks after weaning was 55 percent.

3.9. Inadequate production records

Many pork producers who pen-mate gilts and sows do not have any records to document the reproductive performance of the sow herd. The management adage, "You cannot manage what you do not measure" applies to pork producers. Using a pen-mating system is thought to involve low fixed cost and a low amount of labor and management. Pork producers can make better informed decisions about implementing various types of management procedures to improve reproductive performance when using accurate production records.

4. Possible solutions

Because pen-mating involves unsupervised natural mating between sows and boars, it is impossible to guarantee that all management practices implemented in a pen-mating system will control boar fertility and ensure that all gilts and sows are mated. However, the following management procedures will help increase the possibility that all estrous gilts and sows are mated with a fertile boar.

4.1. Controlling accumulation of estrous females

One way to reduce the excessive number of estrous females accumulating when pen-mating is to use two, three, or four breeding pens or wean sub-groups (***split-wean***) every two to three days ***into two, three, or four breeding pens***. However, there are disadvantages of split weaning: (1) the farrowing area is used over an extended period of time; thus, it is more difficult to use an all-in-all-out facility management system, (2) establishing social hierarchy among sows takes longer to establish, and (3) managing the nursery facility can be more difficult due to the wider age range of piglets. In addition, the period of time the farrowing area is used can be extended due to the variation in length of gestation. The length of gestation can range from 108 to 123 days (Figure 12).

Figure 13 illustrates the estimated number of females in estrus on each day when 20 females are weaned on the same day and pen-mated in one,

two, three, or four breeding pens. The number of females in estrus still accumulates in each breeding pen; however, there are fewer estrous females per pen on each day. A possible advantage to having fewer estrous females per pen per day is that the boar(s) might be able to more easily identify and breed different females. Thus, there is a better chance that farrowing rate and litter size will be improved.

It is well known that fighting occurs between sows that are unfamiliar with each other. Fighting establishes a relative social ranking; therefore, reduce the need for aggression to settle future disputes between sows. Research has indicated that relative stability in social rank is obtained in groups of sows after two to three days. Factors that can influence the number and severity of agonistic interactions between sows after mixing include housing animals outdoors or indoors, space allowance, pen design, group size, composition of the group, and feeding method.

Figure 14 indicates the relationship between the occurrence of fighting and estrous activity when five females per group are weaned four days apart into one breeding pen. Duration of estrus is assumed to be 61, 53, 49, and 38 hours for sows that first express estrus on days three, four, five, and six after weaning, respectively. There will be a substantial amount of fighting when the first sub-group is expressing estrus; however, there will be little fighting for social dominance when the second group of sows are expressing estrus.

Figure 15 shows the relationship between the occurrence of fighting and estrous activity when five females per group are weaned every two days into one breeding pen (90 percent cycle). There will be a substantial amount of fighting when sows in groups one, two, and three are expressing estrus. The number of females expressing estrus on days 5 to 11 after weaning the first sub-group of females ranges from 5 to 8.

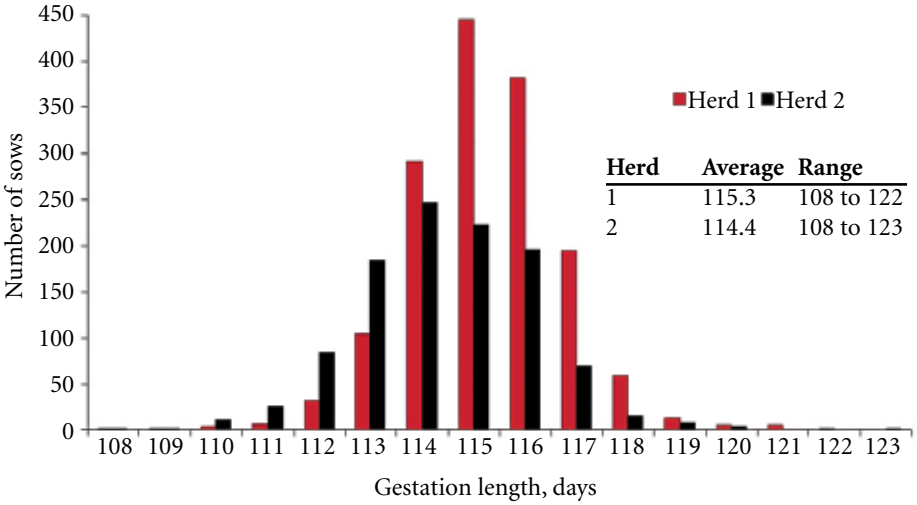

Figure 12. Frequency distribution for length of gestation (English et al., 1982; Stanislaw and Zering, 1984).

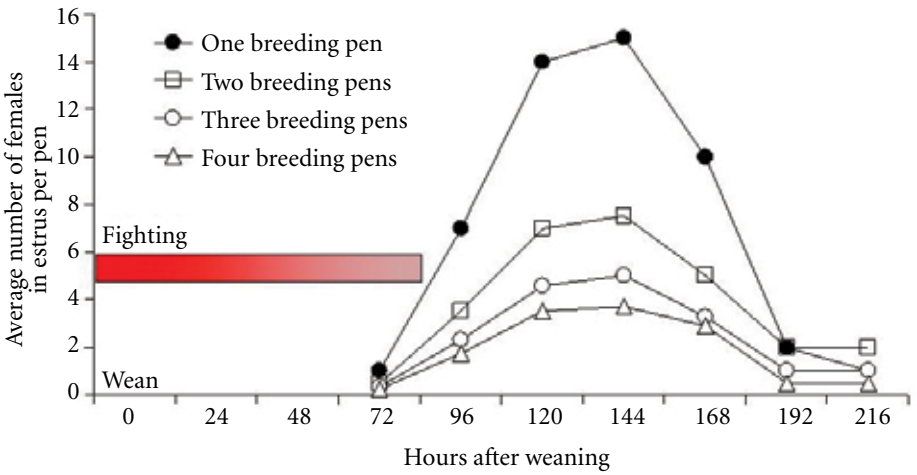

Figure 13. Estimated average number of females in estrus on each day when pen-mated in one, two, three, or four breeding pens. Twenty females are weaned the same day and 90 percent cycle within eight days after weaning.

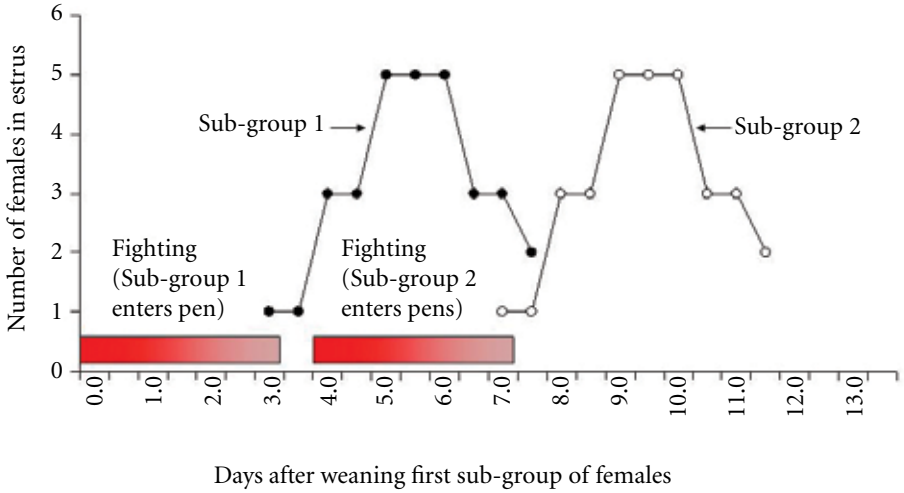

Figure 14. Relationship between the occurrence of fighting and estrous activity when five females per group are weaned four days apart into *one breeding pen*.

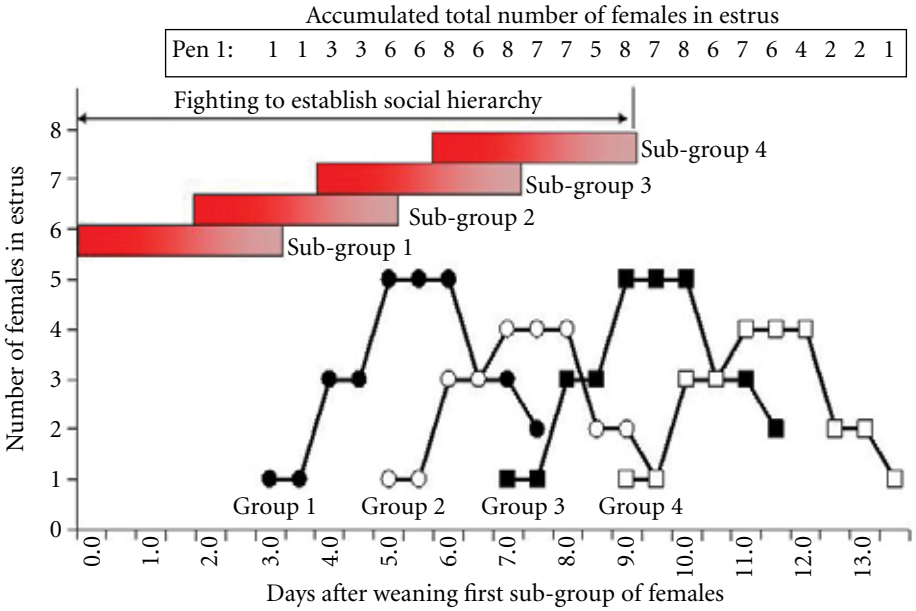

Figure 15. Relationship between the occurrence of fighting and estrus activity when five females per group are weaned every two days into one breeding pen (90 percent cycle).

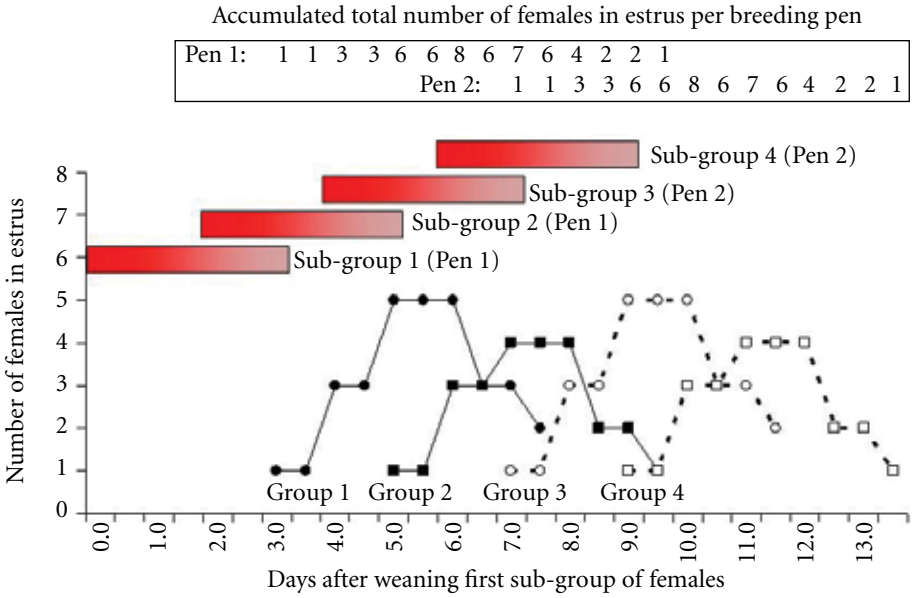

Figure 16. Relationship between the occurrence of fighting and estrous activity when five females are weaned every two days (first two groups enter pen 1 and second two groups enter pen 2; 90 percent cycle).

Figure 16 indicates the relationship between the occurrence of fighting and estrous activity when five females are weaned every two days. The first two groups (group 1 and 2) weaned are placed in breeding pen 1 and the second two groups (group 3 and 4) are placed in breeding pen 2.

Within breeding pen 1 there will be substantial amount of fighting during days three and four after weaning the first sub-group of sows; plus, this period of time is when the highest percentage of group 1 will be expressing estrus. An identical situation occurs in breeding pen 2. The number of sows expressing estrus in pen 1 ranges from six to eight on days five to seven after the first sub-group is weaned.

Figure 17 indicates the relationship between the occurrence of fighting and estrous activity when five females are weaned every two days between two breeding pens. The breeding pens are alternated every two days for sows entering the pen (pen 1 — 90 percent cycle, pen 2 — 80 percent cycle). Although the number of sows expressing estrus on an individual day within a breeding pen is reduced compared to the situation in Figure 16, there is the possibility of a substantial amount of fighting when all the sows are expressing estrus.

4.1.1. Effects of stress on reproduction. A sow can encounter physical activities and environmental conditions that increase the level of stress when pen-mating and gestating sows in a group-housing environment. The effects of stress on reproduction depends on the critical timing of stress in relation to the stage of the estrous cycle, the genetic capability of sows to handle stress, and type of stressor. The two main types of stress involved with pen-mating are physical aggression and insufficient feed intake. Lack of feed intake occurs when sows are not individually fed. A sow that does not cope with these stressful situations may have a reduced well-being and impaired reproductive performance. During the time of pen-mating the continuous interaction among sows and boars occurs when significant biological functions are happening that can influence reproductive performance. Researchers have investigated whether stress that occurs from weaning to 35 days after mating has detrimental effects on hormones involved with reproduction, onset of estrus, estrous expression, duration of estrus, transport of sperm cells to oviduct, onset of ovulation, ovulation rate, duration of ovulation, transport of ova through the oviduct, number of sperm cells attaching to the ova, early stages of embryonic development, implantation of embryos, embryonic survival, farrowing rate, and number of piglets born per litter.

Nutritional stress. When sows are group fed without the use of individual feeding stalls, a substantial amount of fighting occurs. Stress created by food deprivation for 48 hours in sows elevates the synthesis of cortisol and prostaglandin F2 alpha, and affects motility of the oviduct. This leads to a prolonged transport time of the ova as well as a decrease in both the cleavage rate of the embryos and the number of spermatozoa attached to the ova. Food deprivation during days 10 to 14 of pregnancy did not affect total number of fetuses or fetal survival rate at day 30 of gestation.

Physical stress. A stress response is dependant on the nature of stress, intensity of stress, and duration of stressful event. There is a large variation among sows in their ability to cope with stress. Stress levels in a newly formed group of sows may persist for about two days until a dominance order is established. In large groups of sows, physical aggression may continue for 10 to 12 days. The effect of grouping sows on the weaning-to-estrus interval depends on both the level of aggression in the group and the social dominance position of the individual sows. Dominant sows in a group mount lower ranking sows; whereas, the subordinate sows seldom mount dominant sows. Sows that receive the highest amount of aggression have longer weaning-to-estrus intervals and a shorter duration of estrus. Simulated stress induced by injections of ACTH (adrenocorticotropic hormone) during pro-estrus caused a delay in the onset of estrus and the development of cystic follicles in sows. Sows given ACTH from onset of estrus to 60 hours after ovulation had a tendency to have a shorter duration of estrus, larger number of sperm cells in the utero-tubal junction, greater number of sperm cells in oviduct, and a faster transport of embryos to the uterus compared with nonstressed sows. Simulating stress during estrus did not effect early embryo development. A study in the Netherlands reported

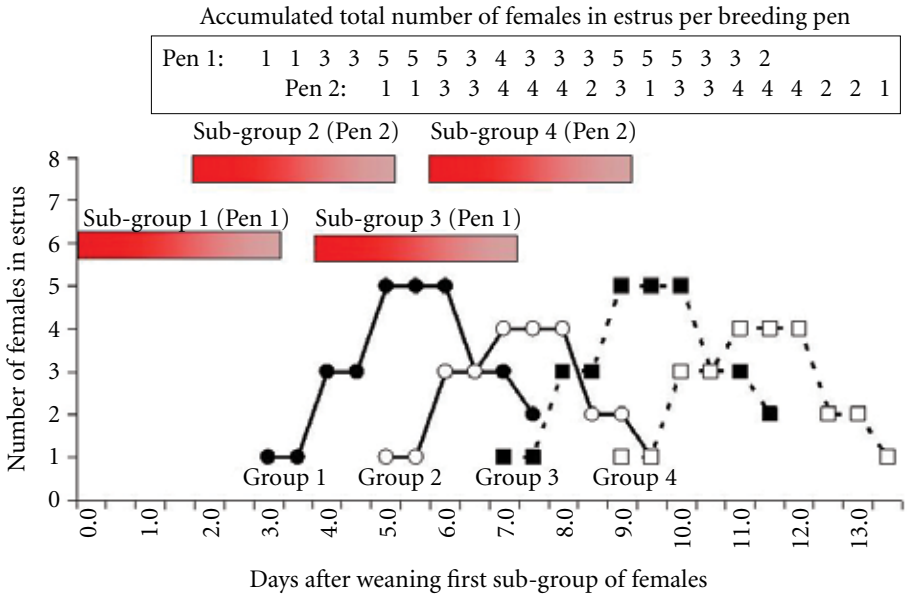

Figure 17. Relationship between the occurrence of fighting and estrous activity when five females are weaned every two days between two breeding pens. The breeding pens are alternated every two days for sows entering the pen (Pen 1 - 90 percent cycle, Pen 2 – 80 percent cycle).

Table 14. Influence of day of mixing after breeding on reproductive performance (Cassar et al., 2008).

Day mixed after bred	Number of sows	Farrowing rate, %	Number piglets born alive per litter	Fecundity index (FI)[a]	FI difference from Day 28
2	98	77.5	10.2	790	-85
7	97	75.3	10.3	776	-99
14	101	72.3	10.7	774	-101
21	101	83.2	10.4	865	-10
28	98	82.6	10.6	875	0

[a]Fecundity index = (farrowing rate x number of piglets born alive) x 100

that acute stressors (nose-sling for five minutes or unpredictable feeding time) during the follicular phase and early pregnancy did not affect follicle development, embryo development, or embryo survival.

When using multiple breeding pens to reduce the number of sows in estrus on the same day in the same breeding pen, the sows will most likely be mixed at a later date. Researchers have investigated the effects of mixing bred sows during various stages of gestation. Because exact breeding dates are not known and the breeding period is at least 21 days when pen-mating, the time of mixing sows is less of a concern compared with a weekly breeding period. Mixing bred sows at 28 days or more of gestation is not detrimental to fecundity index value compared to mixing during the first 14 days of gestation (Table 14).

4.2. Controlling boar fertility

Boar fertility can be influenced by many environmental factors such as season, breed, age, photoperiod, ambient temperature, feed intake, testis size, and ejaculation frequency. The two most important factors influencing reproductive efficiency are ejaculation frequency and ambient temperature.

4.2.1. Ejaculation frequency. An ejaculation frequency of seven times

per week has been shown to decrease motility of sperm cells, decrease total sperm cells, decrease farrowing rate, decrease number of live piglets born, and increase percentage of abnormal sperm cells. Generally, the solution recommended to enhance boar fertility is rotating boars for sexual rest. Boars are easily trained to a daily rotation system: (1) do not feed the boar until the boar has moved from a breeding pen to a pen for sexual rest, and (2) the boar completes eating in his resting pen before moved to breeding pen.

Group-housed boars should be sexually rested out of sight and sound of estrous females and working boars. This procedure substantially reduces homosexual activity, which also can deplete sperm reserves during the resting period. Ideally, boars should be housed individually; however, this requires they be used individually in the breeding pen.

4.2.2. Ambient temperature. Boars exposed to ambient temperatures in excess of 82°F have lower sperm output, poorer sperm motility, and increased morphological abnormalities of the sperm cells. Because of these detrimental effects on semen quality, farrowing rate and litter size can be reduced. In addition, hot and humid weather can decrease the level of a boar's sexual behavior, especially during the daytime. If a boar is subjected to heat stress sporadically over the summer months, it is possible that the fertility of his semen could be reduced during this period as well as a six to seven week period after the heat stress has ended. After a boar has been heat-stressed, it takes 42 to 49 days for a new group of sperm cells to mature within the boar's testicle and epididymis.

It is difficult to keep the boars cool when pen-mating outdoors. To effectively cool, boars need to simultaneously have an adequate shaded area, have water sprinkled on them, and have adequate air movement across their body. One way to increase the possibility of boars being kept cool is to house them indoors during the daytime. When the weather is extremely hot, the boars should only be allowed to work during the evening, night, and early morning hours. This practice can be implemented by not letting the boars eat in sow pen.

4.3. Evaluating sexual behavior and mating ability of boars

The first objective when attempting to solve a perceived problem that a boar has a low level of sexual behavior is **to determine whether the boar is truly sexually inactive or has poor mating ability**.

The highest level of courtship behavior occurs immediately after a sexually rested boar comes in contact with females; thus, a suspect boar should be individually housed overnight out of the sight and sound of estrous females. The following morning, after the boars and females have eaten, the suspect boar should be evaluated for sexual behavior with an estrous female of similar body size for 15 minutes. The boar should be evaluated on his ability to pursue and mount a female, obtain an erection, gain entry into the vagina, and successfully copulate for more than two minutes. A less-effective method to evaluate male sexual behavior is to move a boar from his current breeding pen to another breeding pen. This method of evaluation is less effective because the boar may have recently completed an unobserved mating; thus, diminishing his sexual desire to mate.

It is best to observe boars for sexual behavior early in the morning, especially during hot weather. When the ambient temperature exceeds 86°F, boar sexual behavior starts to diminish. During extremely hot weather, some boars will cease to mate about midmorning and will not resume sexual activity until dark. The majority of courtship behavior and mating occurs between 2:00 a.m. and 11:00 a.m. (Table 15).

4.3.1. Dominate boars. Domination by one boar during courtship and mounting activities in a multi-sire breeding system (two to four boars in same pen) may or may not be a problem. Research has indicated that dominate boars in the pen were responsible for 82 percent of all interrupted copulations in a multi-sire pen-mating system. Subordinate boars are only responsible for 5 percent of all interruptions. Domination by one boar in a multi-sire breeding pen has been shown to be less of a problem when boars are reared together. When domination is not a problem in a multi-sire breeding pen, sexual activity in the breeding pen is enhanced. It appears that when one boar starts expressing sexual activity, the other boars commence sexual activity. Excessive fighting among boars can be a problem when there are not enough estrous females available for all sexually stimulated boars or all boars in the pen prefer the same female. Fighting among boars within a multi-sire breeding system is an inherent problem that cannot be avoided. The only method to prevent fighting among boars is to house them individually and rotate them on a schedule either into or out of the breeding pen. Rotating boars is discussed in section 4.2 and 4.8.

4.4. Increasing the probability of mating at proper time

Rotating sexually rested boars among breeding pens may or may not increase the probability of all estrous females being bred at the proper time. Often, the new boar in the pen mates the same female the previous boar mated; thus, the probability that the female is bred at the proper time is increased. On the other hand, other estrous females may not be mated.

4.5. Reducing injured females

Reducing the number of females injured due to excessive sexual behavior by boars can be prevented by

Table 15. Courtship behavior time and number of matings by 18 boars within each 60-minute period of a 24-hour day (Levis et al., 1997).[a]

Time of day[b]	Sexual activity when not mounted, min.	Duration of time mounted, min.	Number of matings	Time of day	Sexual activity when not mounted, min.	Duration of time mounted, min.	Number of matings
2400 to 0100	14.6	11.4	1	1200 to 1300	4.9	1.6	0
0100 to 0200	28.7	17.8	2	1300 to 1400	14.7	9.7	1
0200 to 0300	64.2	56.1	2	1400 to 1500	6.4	1.6	0
0300 to 0400	58.0	43.5	5	1500 to 1600	16.4	1.5	0
0400 to 0500	82.2	57.3	7	1600 to 1700	27.8	19.4	2
0500 to 0600	96.1	50.2	2	1700 to 1800	6.9	1.3	0
0600 to 0700	51.1	28.4	2	1800 to 1900	9.0	13.4	0
0700 to 0800	69.8	52.2	5	1900 to 2000	0	0	0
0800 to 0900	56.6	38.5	2	2000 to 2100	5.4	2.7	0
0900 to 1000	46.8	55.2	6	2100 to 2200	5.6	7.4	1
1000 to 1100	48.6	32.8	2	2200 to 2300	0	0	0
1100 to 1200	6.4	8.3	1	2300 to 2400	3	4.7	0

[a]The observations were taken for 113 continuous hours when females were coming into estrus, were in estrus, and going out of estrus.
[b]24-hour clock times; 2400 is midnight; 1200 is noon.

Table 16. Proportion of gilts in standing estrus at various times when continuously exposed to mature boars for 21 minutes during heat-checking (Levis and Hemsworth, 1995).

Time of day	Minutes after initiation of estrous detection (continuous fenceline contact with boar)					
	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

not placing the boars in the breeding pen until the afternoon of the fourth day after weaning. This practice increases the number of estrous females available for boars to court and mate.

4.6. Checking bred sows for return to estrus

Pork producers who pen-mate females can easily increase reproductive efficiency (pigs sold per female maintained) by checking for returns to estrus in gestating females. Open or nonpregnant females need to be identified as soon as possible after their first service and either remated or culled. When deciding whether to remate or cull females, consider that the farrowing rate for females rebred at their first post-breeding return to estrus was 65.6 percent, and 51.0 percent for females rebred at their second post-breeding return to estrus, according to one study. The farrowing rate of females mated at first estrus after weaning was 83.6 percent.

If a group of females is weaned on the same day, they can be checked for estrus every other day from 25 to 45 days (first return to estrus after breeding) and 46 to 66 (second return to estrus after breeding) days after weaning. It is assumed that the females are bred during a 21-day breeding period at first estrus after weaning; plus, they start cycling four days after weaning. The majority of bred sows returning to estrus should occur on days 25 to 36 after weaning (18 to 35 days after mating). The key point to remember: do not let females receive boar stimuli (sight, sound, or smell) for one hour before checking for estrus. It has been demonstrated that estrous females become refractory (will not stand in presence of a boar) to boar stimuli within 5 to 10 minutes after exhibiting a standing response (Table 16). Boars that are housed continuously with the

sows have to be removed the night before heat checking the next morning.

4.7. Evaluating physical and environmental stresses on bred sows

Generally, all systems that house sows in groups will require regrouping. Regardless of whether sows are housed indoors or outdoors, some degree of aggression is inevitable when unfamiliar sows are mixed. Aggression among sows at the time of grouping is considered a negative aspect of group housing. It takes two to seven days to reach a relative stability of social hierarchy in a group of newly mixed sows. The presence of a boar at the time of mixing sows has been suggested as a management tool to reduce aggression among sows; however, the results from different scientific studies are contradictory.

A study in England found that boar presence led to a reduced frequency of aggressive interactions and skin lesions of sows during the first eight hours after mixing newly weaned sows. A study in Germany found that having a mature boar (about 2 years of age) in the pen did not affect the total number of aggressive interactions per sow during the first 48 hours following the mixing of newly weaned sows; however, boar presence significantly decreased the number of fights (3.6 vs 6.4; $P < 0.01$) and significantly reduced the duration of fights between sows (14.9 seconds vs 39.6 seconds; $P < 0.01$). A Canadian study found that having a mature boar (about 2 years of age) in the pen did not reduce aggression between females during the first 48 hours after mixing. The sows were mixed at 2 to 28 days after mating.

The welfare and productivity of sows improves when sows are exposed to less physical and environmental stress. Extreme levels of stress may be caused by high stocking density, new social grouping, poor environments, thermal extremes, and human-animal interactions which cause physical and (or) psychological trauma to animals. **All types of physical and environmental stress should be minimized for 28 days after mating.** Some of the reasons to reduce stress include:

- After mating, the fertilized eggs are retained within the oviduct for about two days before they are released into the uterus. If stress causes the eggs to be released into the uterus too early, they will die because the uterus is a hostile environment prior to the normal time the eggs enter the uterus.
- About 10 to 12 days after mating, the blastocysts start to develop into a 39-inch long, extensively folded structure that signals the female to maintain pregnancy. Thus, the level of stress should be minimal when the sow is receiving the pregnancy signal.
- Attachment of the blastocyst to the uterine wall starts around 12 to 14 days after mating and continues until about 28 days. Research studies have found that sows regrouped every two or three weeks during pregnancy tend to have lower farrowing rates compared to sows not regrouped.

Most likely, sows that are group-housed indoors will encounter more stress because they have less space to escape when fighting compared to sows housed outdoors. The distance required for a subordinate sow to escape from an aggressive sow is very important. One study using a dynamic grouping system found the distance over which a subordinate sow is pursued following aggressive interactions can vary from 0 to 66 feet, with 75 percent of the encounters resulting in chase distances of less than 8 feet.

4.8. Estimating number of boars needed

There has been no research conducted to evaluate the influence of various boar-to-weaned female ratios when pen mating, on the percentage of estrous females mated, or number of copulations received per female. Therefore, it is difficult to make absolute recommendations for boar requirements when pen-mating. Generally, the number of females cycling and receptive to the boar on each day of the breeding period and the number of ejaculations by each boar per day are unknown. **The percentage of females pregnant at 30 to 35 days after mating has been reported to be 92 percent for females bred by boars ejaculating once per day for five days and 58 percent for females bred by boars that ejaculated four times per day for five days**. It is not uncommon for boars to ejaculate four or more times per day when pen-mating. Therefore, a conservative approach must be taken when estimating the number of boars to use when pen-mating, especially when it is important that the farrowing rate and litter size born live remains high. The following suggestions will help in determining boar requirements when pen-mating:

4.8.1. All females are weaned the same day. Because the number of females in estrus accumulates over time (Figure 2), it is important to answer the following questions:

- How many females are being weaned?
- How many pens are being used for breeding?
- How many weaned females are being placed in each breeding pen?
- Are some boars going to be moved out of the female pen for a short period while other boars take their place?, and
- How much time are the boars given for sexual rest?

An example of calculating the number of boars needed when pen-mating females that are all weaned the same day is shown in Table 17 (one boar per two females bred) and Table 18 (one boar per four females bred). Regardless of the boar-to-female ratio used, there is no guarantee all females

will be satisfactorily mated during their first estrus after weaning. **However, when following the example in Table 17, a higher farrowing rate and improved litter size may be achievable because more boars are used relative to the number of females to be bred.** Having more boars available at the time when groups of females are in estrus increases the chance that a sow in heat will have a satisfactory mating and increases the chance of her becoming pregnant.

A minimum of five boars would be needed to breed the distribution of 20 females shown in Figure 13 when using the following assumptions: (1) Boar-to-female ratio is one boar to four females to breed (Table 17), (2) two breeding pens are used and (3) each boar is rested for one day. However, because of the many uncontrollable variables associated with pen-mating, there is no guarantee that all 20 females will be mated satisfactorily during the first estrus after weaning.

4.8.2. Female group is split-weaned. The most sensible method for estimating the number of boars needed when pen-mating a group of split-weaned females is to estimate the accumulated number of females in estrus on each day during the breeding period. The factors to consider are: (1) number of days between weaning each sub-group of females, (2) number of females per sub-group, (3) number of breeding pens, (4) distribution of weaned females among breeding pens, (5) rotating boars into and out of breeding pens for sexual rest, (6) length of time for sexual rest by boars, (7) percentage of females first found in estrus on each day and (8) the length of time a female is in estrus.

Table 17. An example of calculating the number of boars needed when pen-mating females that are all weaned the same day.

Total number of females to breed (B)	Ratio Being Used: 1 boar per 2 females bred (A = .5)				
	Total number of boars (C) C = A x B	Number of breeding pens used (D)	Number of boars assigned each pen (E) E = C ÷ D	Number of boars in each subgroup of boars (F)[a]	
				One day of sexual rest	Two days of sexual rest
				F = E ÷ 2	F = E ÷ 3
10	5	1	Pen 1 = 5	Group 1 = 2 Group 2 = 3	Group 1 = 2 Group 2 = 2 Group 3 = 1
10	5	2	Pen 1 = 2 Pen 2 = 3	Group 1 = 1 Group 2 = 1 Group 1 = 1 Group 2 = 2	Not possible to use two days sexual rest Group 1 = 1 Group 2 = 1 Group 3 = 1
20	10	1	Pen 1 = 10	Group 1 = 5 Group 2 = 5	Group 1 = 3 Group 2 = 3 Group 3 = 4
20	10	2	Pen 1 = 5 Pen 2 = 5	Group 1 = 2 Group 2 = 3 Group 1 = 2 Group 2 = 3	Group 1 = 2 Group 2 = 2 Group 3 = 1 Group 1 = 2 Group 2 = 2 Group 3 = 1
20	10	4	Pen 1 = 2 Pen 2 = 2 Pen 3 = 3 Pen 4 = 3	Group 1 = 1 Group 2 = 1 Group 1 = 1 Group 2 = 1 Group 1 = 2 Group 2 = 1 Group 1 = 2 Group 2 = 1	Not possible to use two days of sexual rest

[a]Assumes boars are sub-divided into groups to allow them to be rotated for a one or two-day sexual rest.

4.9. Development of production records

Production records used when pen-mating do not have to be highly sophisticated or computerized. Measurements to evaluate critical success factors are referred to as Key Performance Indicators (KPIs). Although many things are measurable, that does not make them key to the success of a pen-mating program. In selecting KPIs, it is critical to limit them to those factors that are essential to enhancing reproductive performance of the sow herd. Some of the critical success factors that have to be done to accomplish an acceptable reproductive performance of the sow herd include:

- getting a high percentage of sows and gilts successfully bred,
- getting a high percentage of sows and gilts successfully farrowed,
- getting a high number of piglets born live per litter, and
- getting a high number of piglets weaned per litter.

It is essential to have production records that measure the previously mentioned KPIs. A suggested simple data sheet of measuring the KPIs when pen-mating is shown in Table

Table 18. An example of calculating number of boars needed when pen-mating females that are all weaned the same day.

Total number of females to breed (B)	Ratio Being Used: 1 boar per 4 females bred (A = .25)				
	Total number of boars (C) C = AxB	Number of breeding pens used (D)	Number of boars assigned each pen (E) E = C ÷ D	Number of boars in each sub-group of boars (F)[a]	
				One day of sexual rest	Two days of sexual rest
				F = E ÷ 2	F = E ÷ 3
10	3	1	Pen 1 = 3	Group 1 = 2 Group 2 = 1	Group 1 = 1 Group 2 = 1 Group 3 = 1
10	3	2	Pen 1 = 2 Pen 2 = 1	Group 1 = 2 Group 2 = 1 Not possible to use one day of sexual rest	Not possible to use two days sexual rest Not possible to use two days sexual rest
20	5	1	Pen 1 = 5	Group 1 = 2 Group 2 = 3	Group 1 = 2 Group 2 = 2 Group 3 = 1
20	5	2	Pen 1 = 2 Pen 2 = 3	Group 1 = 1 Group 2 = 1 Group 1 = 1 Group 2 = 2	Not possible to use two days sexual rest Group 1 = 1 Group 2 = 1 Group 3 = 1
20	5	4	Pen 1 = 1 Pen 2 = 1 Pen 3 = 1 Pen 4 = 2	Not possible to use 1 day of sexual rest Not possible to use 1 day of sexual rest Not possible to use 1 day of sexual rest Group 1 = 1 Group 2 = 1	Not possible to use two days of sexual rest

[a]Assumes boars are sub-divided into groups to allow them to be rotated for a one or two-day sexual rest.

19. A gradual but continual improvement in reproductive performance of the sow herd can be accomplished by using a continuous improvement cycle of planning, implementing the plan, evaluating the KPIs, and taking action to make needed changes.

It is important that pork producers who pen-mate sows keep good records related to:

(1) farrowing rate for sows mated at first service after weaning; (2) total number of piglets born and number of piglets born alive per litter for sows mated at first service after weaning; (3) number of boars and age of boars used for breeding; (4) management procedure used for breeding sows, such as, rotation of boars for sexual rest, number of days boars are sexually rested, number of boars simultaneously used in the breeding pen, number of sows in the breeding pen(s), and procedure for weaning sows into the breeding pen; (5) dates the breeding period occurred, and (6) whether boars are run with the sows to breed sows that return to service during a 21-day period after their first service. This data can help pork producers make improvements for increasing reproductive performance of the sow herd.

5. Outdoor pen-mating facility design

The layout of breeding facilities for pen-mating outdoors will vary enormously according to the number of sows in the breeding herd, number of groups of sows, number of sows per group, soil type, topography, amount of land area available, geographic location, and various management procedures.

The main principles to consider when designing and managing an outdoor pen-mating facility include: (1) method of housing boars, (2) method for ease of rotating boars into and out of a breeding pen, (3) number of recently weaned sows per breeding pen, (4) amount of feeding space per sow and ease of feeding sows either individually or in a group, (5) requirements for maintaining fences and ground within the pen, (6) ease of administering vaccinations and medications for sows, gilts, and boars, (7) ease of accurately detecting open sows and gilts after mating, (8) ease of removing sows and gilts from a breeding pen, (9) method for watering sows, gilts, and boars, (10) method for cooling sows, gilts, and boars during hot weather, and (11) method of providing bedding to sows, gilts, and boars.

An example of an outdoor pen-mating facility is shown in Figures

Table 19. Breeding group record for pen-mating of sows and gilts.

Group I.D. _____										Page ____ of ____ pages		
Breeding pen I.D.:	Pen ID:			Pen ID:			Pen ID:			Pen ID:		
Date boar(s) in pen												
Date boar(s) out of pen												
I.D. of boars used												
Date first sow placed in pen												
Date last sow placed in pen												
Estimated farrowing dates												
Comments:	Sow ID	Pigs born alive	Pigs weaned	Sow ID	Pigs born alive	Pigs weaned	Sow ID	Pigs born alive	Pigs weaned	Sow ID	Pigs born alive	Pigs weaned
Total:												

Calculated group statistics:

A. Total number of sows and gilts exposed: _____

B. Total number of sows and gilts farrowed: _____

Farrowing rate (B/A): _____

C. Total number piglets born alive: _____

D. Total number of piglets weaned: _____

Pre-weaning death loss, % (D/C): _____

Average number piglets born alive per sow farrowed (C/B): _____

Average number of piglets weaned per sow farrowed (D/B): _____

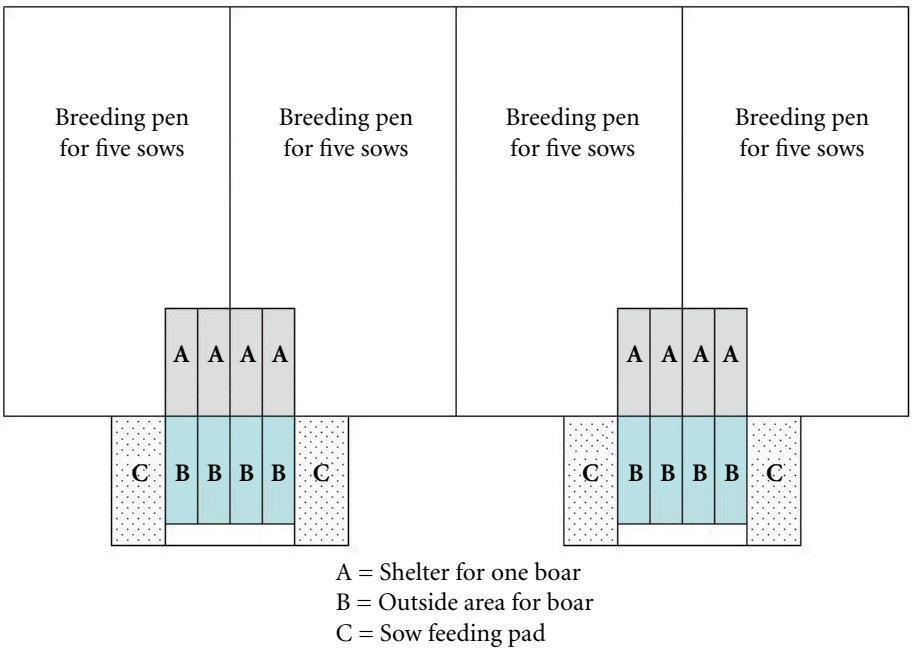

Figure 18. Schematic of an outdoor pen-mating facility

Figure 19. Pen-mating in outdoor dirt lots with individual boar housing.

18 and 19. The facility is designed to individually house boars, easily move boars into and out of a breeding pen, and easily and safely feed sows and boars on a concrete pad. The boars are trained to a daily rotation procedure by always feeding them in their home pen. The feeding pad allows an easy way to catch the sows for medical treatment or loading them for transport to a gestation pen. Be sure all gates and gate latches are designed for easy opening and closing. Make sure all gates swing in an appropriate manner and direction. As seen in Figure 19, overhead braces are used to make sure the gates easily swing and lock. Some pork producers use a more permanent procedure to reduce the requirements needed to maintain a fence by placing a steel post in a concrete footing (Figure 20).

The amount of land needed for the breeding pens depends on soil type, drainage, slope, number of animals per pen, and whether pasture is used. It has been recommended that five sows and one boar on pasture require 3,588 square yards.

6. Indoor pen-mating facility design

Some pork producers have moved their sows indoors because of the ongoing requirement for maintaining fences, mud lots, and serious problems with snow and ice (Figure 21). Indoor pen-mating facilities should be carefully designed and constructed to provide animal comfort, ease for moving animals, individual housing of boars, and enhancement of reproductive performance.

6.1. Boar housing

Ideally, boars should be housed individually rather than as a group. The benefits are: (1) reduction of injuries from fighting and riding, (2) stimulation of sexual behavior, (3) simplification of moving them in and out of their living space, (4) elimination of homosexual activity, and (5) allow for feed intake adjustments to maintain proper body condition. These benefits extend the useful life of the boars and reduce costs due to the need for fewer replacement boars.

6.1.1. Floor space and surface. The amount of floor space allowed per boar is generally 35 to 50 square feet. The floor should be partially or totally slatted to prevent a mucky environment. When using a partially slatted floor, the boars are fed on the floor. The alley is raised 4 inches to prevent the boars from moving feed into the alley.

6.1.2. Pen dimensions and gate latch. The minimum width of the pen is 5 feet, however, 6 feet is preferred. The pen partitions should be 46 to 48 inches high and constructed of vertical pipe to prevent climbing. Vertical

pipe should be placed 4 to 5 inches apart. The bottom horizontal pipe should be no more than 8 inches off the floor between adjacent pens and only 6 inches off the floor next to the feed alley. Boar pens should have a gate latch that can be opened and shut quickly, yet not be opened by the boar.

6.1.3. Ventilation, heating, and cooling. The resting area for individually housed boars should be totally enclosed because there is not enough body mass to generate sufficient heat to warm the boars. The boar living area is not large; therefore, the cost of installing and operating a mechanical ventilation system is reasonable. During warm seasons, boars are generally cooled with an intermittent spraying system combined with fans. It is the evaporation of water that cools the boars; therefore, it is best to spray the boar until wet, set the timer to turn off the water until the boar dries off, and then repeat the cycle. Moving air across the boar with a fan helps ensure that moisture is being removed, and increases the evaporation process during extremely hot weather.

6.2. Sow housing

When pen-mating indoors, the number of weaned females per pen should be kept small, about 4 to 10 sows. The floor plan indicated in Figure 22 houses seven females with one boar (18 square feet per animal).

6.2.1. Floor space and surface. The floor space allowed per female is generally 18 to 20 square feet in the breeding pen and 16 square feet in gestation (14 square feet for gilts). Normally, females are pen-mated on a partially slatted floor. Imprinting a diamond pattern (4- to 5-inch o.c., one-half inch deep) in the breeding pen floor helps prevent injuries when females are mounting or being mounted by other females or a boar. Feeding females on the floor helps keep it clean and dry. Raising the alley 4 inches above the breeding pen floor prevents the females from moving feed back into the alley.

Figure 20. Outdoor fencing method to help prevent sows from tearing-up the fence.

Figure 21. Serious problems with snow can occur when pen-mating sows in outdoor lots.

6.2.2. Pen partition and gate latch. Normally, a 48-inch high pen partition is used to prevent females and boars from getting into an adjacent pen. In a partially slatted facility, a solid pen partition is used on the solid portion of the floor to enhance a good dunging pattern; however, a solid pen partition interferes with air flow. To enhance air flow and still have an effective 48-inch high partition, set a pipe or steel rod panel on top of a 32-inch concrete wall (Figure 23). Breeding and gestation pens also should have a gate latch that can be opened and shut quickly and yet cannot be opened by animals. Open partition gates are used along the alley, so estrus detection can be easily accomplished during the gestation phase.

6.2.3. Ventilation, heating, and cooling. The facility shown in Figure

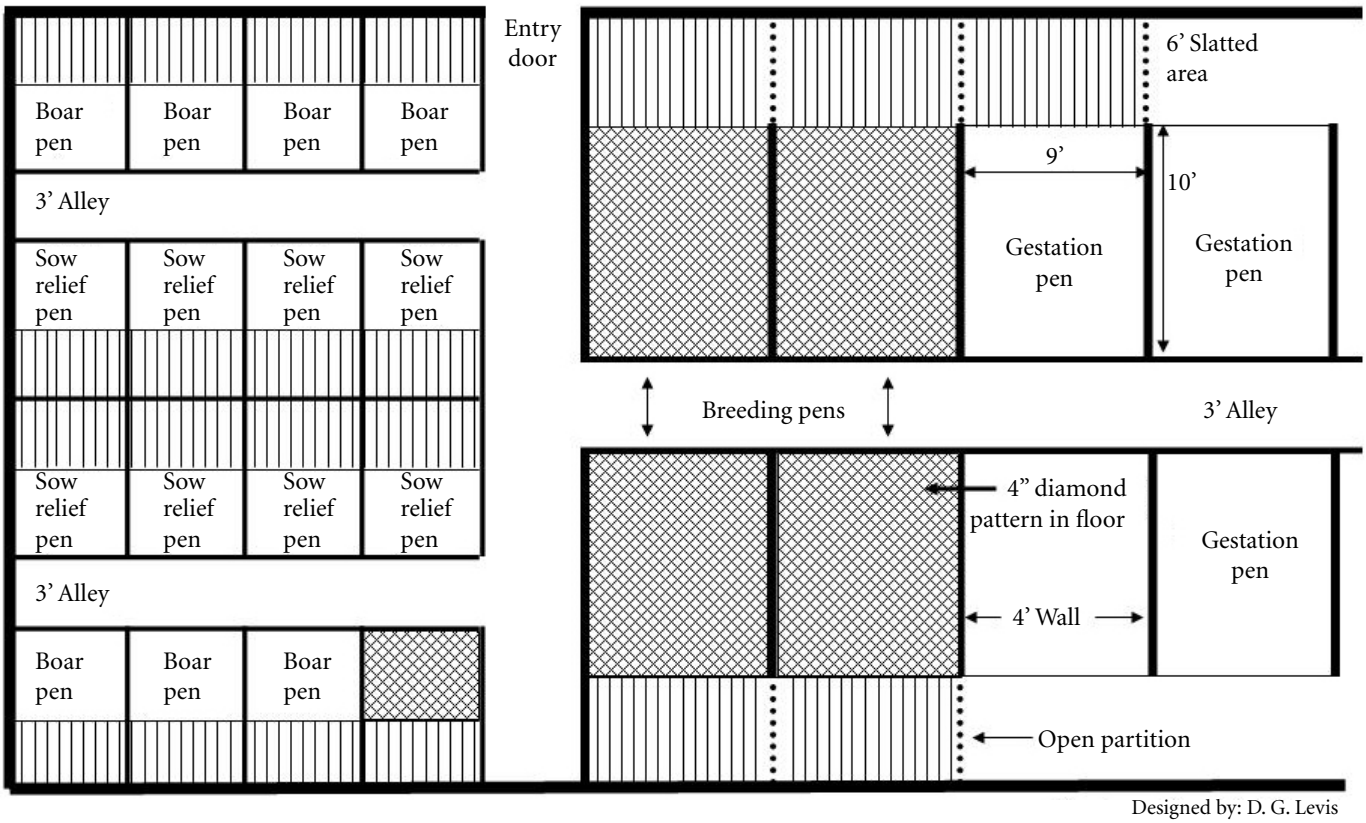

Figure 22. Example of an indoor pen-mating facility.

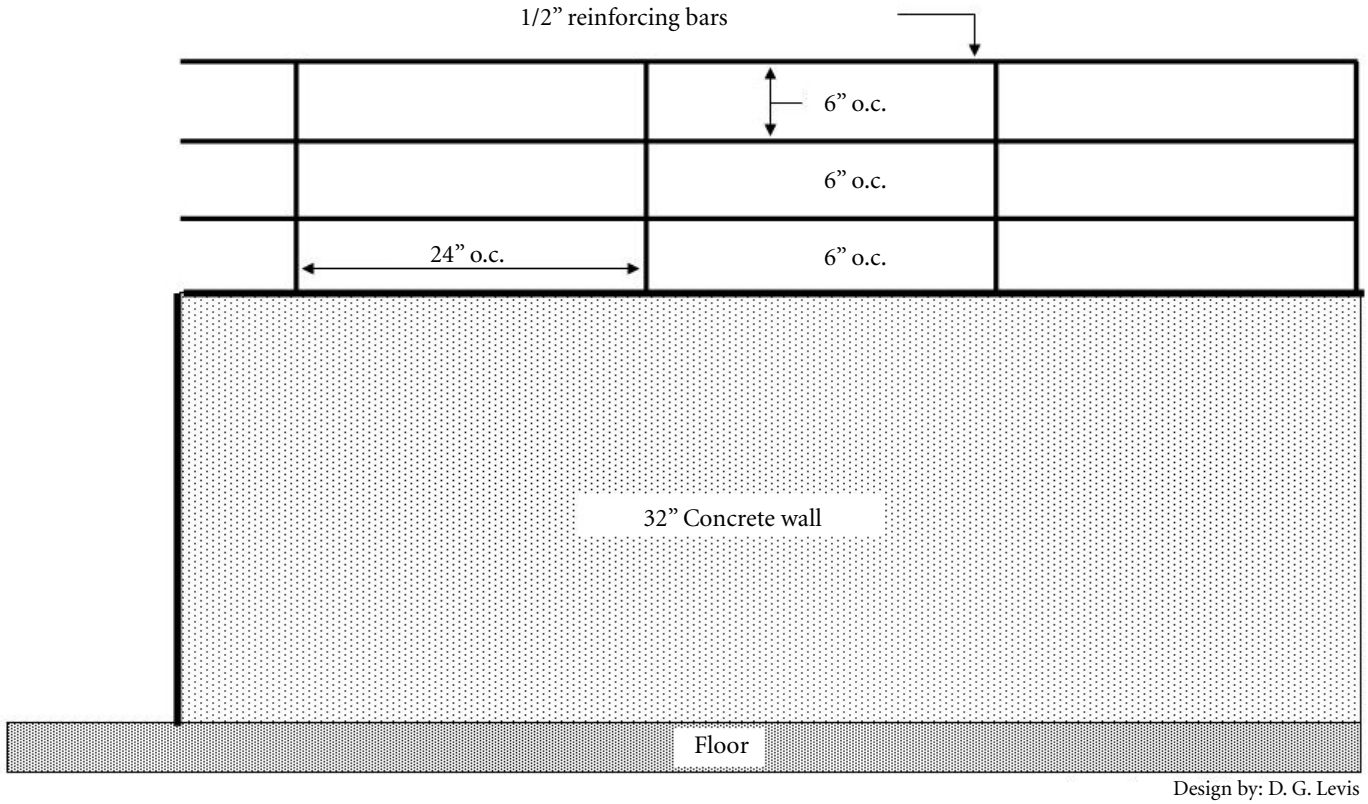

Figure 23. Example of a pen partition to allow air movement.

22 is a gable or "A" roof building. The building is operated as a nonmechanically ventilated, modified open-front facility.

7. Hand-mating

Pork producers who change from pen-mating to hand-mating find the time spent hand-mating more than pays for itself. Reproductive performance of a farm that changed from pen-mating to hand-mating is shown in Table 20.

Table 20. Reproductive performance on a commercial farm that changed from pen-mating to hand-mating (Levis – unpublished data).

Year	Method of Mating	Avg. number of females on inventory	Number females farrowed	Litters per female per year	Number of pigs farrowed	Number of pigs weaned	Pigs per sow per year
1	Pen-mated 12 months	140	219	1.56	2061	1849	14.39
2	Hand-mated four months and pen-mated eight months	140	246	1.76	2587	2145	16.69
3	Hand-mated 12 months	111	259	2.33	2809	2412	21.72

During a 12-month period this farm had pen-mated the first four months, hand-mated the middle four months, and pen-mated the last four months. When the reproductive data was summarized, the farrowing rate and litter size was lower for pen-mating compared to hand-mating. When a 12-month period of hand-mating was compared to an earlier 12-month period of pen-mating, the improvement in reproductive performance when hand-mating was:

- 0.2 percent increase in pigs weaned per litter
- 15 percent increase in pigs born live per litter
- 30.5 percent increase in total number of pigs weaned
- 36.3 percent increase in total number of pigs born live
- 49.4 percent increase in litters per female per year
- 51 percent increase in pigs weaned per female per year

The increase in reproductive performance when hand-mating was done with a 20.7 percent decrease in average number of females on inventory. Some factors that improved reproductive performance were: better control of boar fertility; a tighter production schedule due to knowledge of exact breeding dates; bred females regularly heat-checked to identify open females; and females returning to estrus after their second mating were culled.

8. Production scheduling

Most pork producers who pen-mate sows have a diversified farm; thus, they cannot devote total time and management to the swine enterprise. These pork producers seasonalize the production of pigs around their cropping plans. The development of a yearly production schedule for the sow herd helps optimize the use of production facilities to enhance control of diseases (especially in the farrowing and nursery buildings), labor, and feed. In addition, the periods of time when the sows and gilts are to be bred are clearly identified; thus, the date the boar(s) should be removed from the breeding pen is established.

Batch breeding, farrowing, and weaning enables small farms to produce larger groups of pig at regular intervals instead of small groups of pigs. A disadvantage of interval batch breeding is that females failing to conceive and re-bred accumulate more nonproductive days than females in a conventional weekly breeding scheme. These females return to heat at the wrong time according to the breeding schedule. Two publications to help pork producers develop a swine production schedule and calendar of management activities for their particular situation can be found in the Pork Industry Handbook (2001 CD-ROM Edition). The title of the publications is: 1. Calculating Swine Schedules, and 2. Pork Production Systems with Business analyses: Two Groups of Sows Farrow-to-Finish. The Iowa Pork Industry Center at Iowa State University has a computer template available that calculates production schedules. This computer template can be used to production schedule one group of sows to farrow twice per year.

9. Glossary

Blastocysts — an early stage embryo having the form of a hollow fluid-filled round cavity.

Boar — an intact male used for breeding gilts and sows

Dynamic mating system — One or more boars are placed with a group of females and mating takes place with no supervision. The females in the pen are changed one or more times during the breeding period.

Embryo — an organism in its early stages of development, especially before it has reached a distinctively recognizable form (pig).

Estrus (heat) — The time during the reproductive cycle in pigs when the female displays interest in mating and will stand to be mounted by both sexes and mated by males. Estrus generally lasts 40 hours in gilts and 55 hours in sows, but variation among individuals can be substantial (range 12 to 84 hours). The first day that estrus is observed is usually designated as day 0.

Estrous — the adjective for the word estrus. Example of use is "the estrous cycle."

Estrous cycle — is the recurrent set of physiological and behavioral changes that take place from one period of estrus to another. Nonpregnant gilts and sows normally have a 21-day estrous cycle, but the estrous cycle can vary from 18 to 24 days.

Farrowing — giving birth to piglets.

Farrowing rate — The proportion of breeding females which farrow from a cohort of females served. The formula is: number of sows farrowed divided by the number of sows serviced during the first 21-day breeding period after weaning multiplied by 100.

Fertilization (also known as conception, fecundation, and syngamy) **—** the process whereby a sperm fuses with an ovum, which eventually leads to the development of an embryo.

Gestation — conception and development of piglets. The average duration of pregnancy in swine is 114 to 115 days (range of 108 to 123 days).

Gilt — a young female pig that has not farrowed her first litter.

Litter — the group of pigs born to a sow or gilt during one farrowing. There are normally six to 12 piglets born live per litter.

Mating — is the physical process of a boar breeding an estrous sow during a service period.

Multiple mating — a sow is bred two or more times during a service period.

Multiple service — a sow is given two or more opportunities to get pregnant.

Nonproductive sow days — is the number of days a sow is neither lactating nor gestating

Service — the period of time the boar is in the breeding pen.

Uterine body — a small structure where the pig's uterine horns unite.

Ovulation — the process in the female pig by which a mature ovarian follicle ruptures and discharges an ovum (also known as an oocyte, female gamete, or an egg). Ovulation typically occurs at about two-thirds into an individual gilt's or sow's estrus (usually 30 to 40 hours after onset of estrus); however, time of ovulation can vary from 24 to 96 hours after onset of estrus.

Ova — the plural form of ovum. Ova are also called eggs.

Repeat service — a sow that returns to estrus either normally or abnormally after mating.

Uterus horn — a hollow muscular organ in which the fertilized ova implant. The ova develop into piglets. A female pig has two large uterine horns that accommodate many fetuses simultaneously.

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