Animal Well-Being

Group Housing Systems: Forming Gilt and Sow Groups

The statements and opinions expressed in this article are those of the author(s).

Objectives

1. Describe the timing of reproductive events in the life-cycle of gilts and sows
2. Define the stall and its use in reproductive management
3. Describe the effects of stress on reproduction in female swine
4. Describe the development and management of gilts and group formation
5. Describe the systems and implications for forming sows groups

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Introduction

Many pork producers are deciding how they will house their breeding and gestating sows and gilts in the future as they remodel existing gestation barns or build new sow housing facilities. However, when sow and gilt groups are formed, significant stress and injuries occur as the animals fight to establish social order in the competition for space and feed, which can lead to compromised animal welfare and reproductive failure [1]. Aggressive interactions can increase culling and reduce sow longevity, and may be related to failure to express estrus and establish and maintain pregnancy, which are the most common reasons for culling and replacement of sows and gilts [2-4]. The methods for forming breeding herd groups are critically important to maintaining gilt and sow welfare, herd reproductive performance and the sustainability of pork production.

Physiology of reproduction and the implications of stress on reproductive events

Sow and gilt fertility ultimately relies on a precise cascade of hormonal signals. These hormones originate in an area of the brain called the hypothalamus where gonadotropin releasing hormone (GnRH) is released. The secretion of GnRH is stimulated or inhibited by the central nervous system that senses both external (the animal's surroundings) or internal (within the body of the animal) signals. When released, GnRH travels to the pituitary gland to cause release of follicle stimulating hormone and luteinizing hormone (LH). Both hormones travel by the bloodstream to the ovaries where they act to stimulate follicle and egg maturation, hormone production (i.e. estrogen), ovulation (release of eggs into the oviduct), and development of the uterus for pregnancy. Various stressors can disrupt events in this process resulting in reproductive failures among prepubertal and mature replacement gilts as well as newly weaned and gestating sows.

Critical events during the first week after breeding

The first critical reproductive process involves follicle selection and maturation for ovulation, which in essence, sets the upper limit for litter size. Follicles selected in the week ahead of mating must grow and produce increasing amounts of estrogen to stimulate the brain for expression of estrus and aid the reproductive tract in the movement of sperm and eggs. There are conflicting data for fertility when mating gilts at pubertal, second or third estrus. It has been reported that gilts that naturally express puberty at young ages increase ovulation rate with subsequent cycles [4]. Further, in gilts induced into puberty with gonadotropins, ovulation rate is often lower [5] and farrowing rate and litter sizes are reduced when mating at the induced rather than the subsequent estrus [6, 7]. However, in puberty attained naturally from use of boar exposure, within the range of 180 to 210 days of age, mating at pubertal estrus did not affect ovulation rate, farrowing rate or litter size [8]. Evidence suggests that the growth rate and body maturity of gilts helps to advance age at puberty which has been associated with increased lifetime fertility and longevity when compared to gilts with lower growth rates and later ages at puberty [9-11]. In weaned sows, both low and high ovulation rates may be problematic. In parity 1 or 2 sows, those with short lactation lengths or sows with compromised body condition, ovulation rate may be lower than the maximal litter size potential. In contrast, in more mature sows from highly fertile genetic lines, ovulation rates may be too high, leading to increased

#03644-3/13

embryo crowding within the uterus, and potentially resulting in reduced litter size or low birth weight pigs.

With most commercial breeding sows being housed in individual stalls and mated almost exclusively using artificial insemination (AI), estrus expression and detection with boar exposure is a key factor to sow fertility [12]. Fence-line or alleyway boar exposure is a practical and effective method for detection of estrus for sows housed in stalls [13-15]. In this system, either a technician or robotic boar mover slowly advances one or more boars in the alleyway in front of each sow while the back-pressure test is applied by a technician. For medium and large sized farms with stall housing, moving large numbers of sows out and back into their stalls each day is impractical and estrual sows become stationary and cannot be moved back to their stall for some time. However, it is important to note, that for gilts, direct physical boar exposure has been reported to be more stimulatory to puberty compared to fence-line contact [16-18] while this effect is not evident when inducing puberty with gonadotropins [5].

In group sow housing systems, vasectomized boars are often used when using physical boar exposure in the pen of sows or gilts, while intact boars can be used when moving boars in the alleyway near then pen, or with permanent housing adjacent to the sow pen. Although direct boar contact [19] and fence-line exposure [15] are each commonly used, there is no evidence to suggest an advantage of one over the other for weaned sows. A review by Kemp et al. [20] in group-housed sows did suggest variable effects of grouping sows immediately after weaning on onset, duration, and expression of estrus. In this review, it was indicated that group size, space allowance, and the social status could affect the estrual responses on the sow. It is important to recognize that in larger groups of females exposed to boars at daily intervals, it can be difficult to ensure that the proper amount of boar exposure is provided to each individual within the entire pen.

Once females are identified in estrus, AI can be performed with maximum fertilization rates resulting if semen is deposited within 24 h before ovulation. The fertilized eggs (now called embryos) will be moved from the oviduct into the uterine horns approximately 4 days after mating. Under optimal conditions, embryo development continues with corpora lutea formation and production of progesterone.

Critical events during the second week after breeding

At days 12 to 14 post-mating, the embryos produce estrogen to signal the mother that they are present and initiate the physiological changes in the female that allow maintenance of the corpora lutea and continued progesterone production. At least 4 viable embryos must be present 13 days after breeding to ensure that most of the uterus receives the embryo signal to establish pregnancy. Implantation begins after the end of the second week of gestation. However, there is considerable evidence of excessive early embryonic mortality in swine [21] and embryo survival is estimated at only 60 to 70%. If the embryos or mother are disrupted by factors such as heat stress or chronically elevated cortisol after the second week post-mating, reproductive failure may occur as a result of an altered embryo signal or failure of the mother to respond to the signal. As a result, the sow may either recycle 21 days after mating or if she received only a weak signal, could result in a delayed or irregular return to estrus.

Critical events during the third and fourth week after breeding

As gestation progresses into the third and fourth weeks, the embryos and placental membranes continue their development and attachment to the uterus. Disturbances at this time period resulting from stress, infection, or toxins could alter the mother's uterine function, growth of the embryos, or the production of progesterone by the ovaries. In any of these instances, pregnancy failure can occur or embryo growth may be abnormal resulting in increased numbers of small or degenerating embryos. In the case of slowed embryo growth, by as early as week 4, the "runts" in the litter can be recognized. At the start of the fourth week of gestation, fluid begins to accumulate rapidly in the uterus within the placental membranes of each conceptus, which is used to identify pregnancy using real-time ultrasound. Frequently, small litters show limited fluid, while females that are losing a pregnancy (aborting), may show fluid with cellular debris.

Critical events during the fifth and sixth week after breeding

In weeks five and six of normal pregnancy, the embryo begins its transition into a fetus. At this time, uterine space may become limiting and will play a role in determining final litter size and fetal growth. As gestation progresses, fetal growth and development continues until farrowing. Collectively, the evidence suggests that sows or gilts exposed to stressors that result in significant physiological changes during almost any stage of reproduction, could result in a disruption of normal hormone production, reproductive tract development and function, and embryo and fetal survival.

The effects of stress on the welfare of gilts and sows and their reproductive life cycle

Stress causes detrimental effects on health, immune function, and reproduction [22] and can be classified as acute (short-term) or chronic (long-term). In both cases, the hypothalamus is activated to release corticotropin releasing hormone which causes the pituitary gland to secrete adrenocorticotropic hormone (ACTH). This hormone travels through the blood stream to induce the adrenal cortex to release cortisol into circulation. Multiple stressors applied during gilt development such as elevated temperature, limited floor space, and social regrouping have been shown to have additive effects on immune function, behavior and growth [23]. A review of the effects of chronic stress on gilts, resulting from crowding, size of the group and negative handling, reported great variability among gilts in negative effects on reproduction. While most gilts exposed to stress may not show any adverse effects on reproduction, there is often a third of the gilts that show susceptibility [24], but with no measure obtained to suggest why certain gilts were affected and others were not.

A major problem that causes stress in pigs is the aggression that occurs when sows or gilts are commingled. The health and well-being of these animals can be assessed in numerous ways such as the presence of wounds, lameness and altered immune responses. When commingled, sows often display aggression toward pen-mates and may exhibit a number of vices such as vulva biting [25]. Aggressive interactions occur within the first few hours after grouping sows. However, aggression is often less with larger sized groups. It is reported that after mixing unfamiliar sows, social aggression may ensue for 2 to 7 days before the group becomes stable. In comparing groups with only three gilts per pen to those in individual stalls during the first 30 days of gestation, the group housed gilts had more lesions over most of their body. Although the severity of the lesions decreased in the days after group formation, by day 30, there was a higher incidence of lameness in the group-housed gilts [26]. Interestingly, pigs with previous housing in a large group displayed less aggression when mixed in groups when compared to pigs that were previously in smaller sized groups [27]. Despite the fact that these aggressive interactions last only a few days, they can have long-term consequences on animal physiology, lesions, and lameness. For example, Kemp et al. [12] reported that throughout gestation, group-housed females had more head and body lesions when compared to those housed in stalls. Notably, by day 91 of gestation, the feet and legs of the group-penned gilts were in poorer condition compared with those in stalls.

Measuring cortisol elevations in the blood or saliva is used to determine the stress response in pigs. Cortisol often increases soon after an acute stress and levels in blood remain elevated for only a short period of time. However, it is thought that if reproductive processes are to be affected, chronic stress lasting for more than 4 days may be required [24]. Chronic stress that elevates ACTH and cortisol for extended periods has been shown to inhibit LH release during the follicular phase of the estrous cycle and at ovulation [28]. The effects of chronic stressors on cortisol secretion are more difficult to ascertain because cortisol can be influenced by daily rhythms, sampling method, and the interval between stress and sampling. A few studies have compared cortisol concentrations in the blood of sows individually housed in stalls or maintained in groups, but data are equivocal. Estienne et al. [26] and Kaneko and Koketsu [29] reported greater cortisol concentrations for sows housed in stalls compared to group-housed animals. In contrast, Patterson et al. [17] reported similar cortisol concentrations for sows in stalls and those in groups. While chronic stress may increase cortisol release from the adrenal gland as a result of increased sensitivity to ACTH, Deligeorgis et al. [16] reported that no differences in cortisol response to ACTH were detected for gilts housed individually or in group pens fed using an electronic sow feeder (ESF).

Types of Stalls

Conventional stalls. Although there is some variation in size and shape, conventional stalls are typically 2 ft. wide x 7 ft. long x 3.3 ft. high and commonly located on fully- or partially-slatted concrete floors. The stall may have a feed and water trough, or nipple watering system. Stalls are most often connected in continuous sets of 10 to 200 and run longitudinally the length of the building. Some stalls have slanted fronts, are less than 7 ft. long and shorter in height. These dimensional factors in relation to the size of the animal may affect posture and behavior of gestating animals [30]. Reports of sow size and growth show that sow body depth increases with gestation and that a small proportion of older parity sows may be too wide while standing and too deep when lying to fit within a conventional stall [31, 32]. Further, Anil et al. [33] reported that injury score of sows increased when there were low ratios of stall length to sow length and stall width to sow height.

Turn-around stalls have had limited use in commercial sow housing. However, studies have reported that gilts housed in these spend more time standing, actively manipulating the stall and chains and have lower cortisol levels during the first 5 weeks of gestation compared to those housed in conventional stalls. Despite these observations, there was no difference in pregnancy rate [34]. Little information is available to suggest that the use of the turn-around stall could benefit reproduction, and the use of these devices can create problems for large sows that cannot turn around easily.

Free access stalls may help reduce stress and aggression and improve reproductive performance if sows or gilts can be locked in for feeding, reproductive management and to limit aggression for certain animals when needed [35].

Forming gilt groups for breeding and gestation

Housing and forming gilt groups. Gilt housing and management are an essential part of the success of the breeding herd. Gilts make up the largest proportion (20 to 30%) of all parities [36] in the breeding herd due to an annual sow replacement rate in excess of 45%. Failure in replacement gilt fertility can lead to a cascade of problems as producers attempt to maintain breeding group size. Reduced gilt fertility can often lead to repeated mixing, crowding, breeding less mature or over conditioned gilts, and retention of less productive sows. Replacement gilt failure has been reported at 19%, with approximately 50% of the failures attributed to reproduction alone. Among gilts that fail to display pubertal estrus, slaughter data suggests nearly half are cycling [37], which suggests some unknown factors which limit expression or detection of estrus.

Housing gilts during the development phase. There is much variation in how replacement gilts are acquired and housed prior to entry into the breeding herd. Survey data indicates that most commercial producers purchase their replacement gilts [38]. Many farms purchase very young gilts at weaning to improve health stability [39], while others purchase gilts at older ages or raise their replacements internally. Gilt selection can occur at any age, but many farms choose to make an initial gilt selection near day 100 based on defined criteria, with regrouping and relocation of the selected females.

Modern farms are increasingly making use of gilt development units (GDU) which are separate buildings that can use all-in, all-out or continuous flow technology for the rearing of replacement gilts. In the GDU, isolation and acclimation to the sow herd diseases are important since replacement gilts often have a higher health status than that of the receiving sow herd, and gilts that become sick can de-stabilize the health of the entire sow farm. In parity segregation systems, gilts are often housed in separate buildings on separate sites with site-specific employees. These gilts are managed separately from the sow herd up to the time of weaning their first litter or mating, before movement into the main sow herd.

During development, gilts are often housed in groups ranging from 10 to 120 head. Regardless of the size of the group, females must be provided adequate floor space that does not restrict access to feed and limit potential for ADG during the grow-finish period. Gonyou et al. [40] used an equation to determine the minimal floor space constant based on body weight (kg) to determine the minimum floor space that would not limit growth rate during development (($0.035\ m^2 * BW^{0.667}$ (kg)), which can then be easily converted ($m^2 * 10.764$) to sq. ft./gilt in pounds. Tests of gilt floor space during development (75 to 200 days of age) with 15-22 gilts/pen, also showed that when comparing the limit established for floor space for gilt growth (0.77 m^2/gilt or ~8.3 sq. ft./gilt) to greater floor space (1.13 m^2/gilt or ~12 sq. ft./gilt) there was no effect on growth rate. However, the greater floor space allowance resulted in a greater percentage of gilts attaining puberty at a younger age and those with earlier puberty produced more pigs up to the third parity [41]. In mature cycling gilts, Hemsworth et al. [42] evaluated 1, 2 or 3 m^2 of floor space for gilts that had already expressed their third estrus at the time of grouping into pens of 6. Evaluation of gilts 21 days later showed that gilts with the least amount floor space had the greatest elevation in cortisol and a lower expression of estrus. The authors indicated this was evidence of the effect of a chronic stress that impacted reproduction.

For developing gilts, feeding is most often performed on an *ad libitum* basis until the time of puberty. It has been shown that feed restriction or inadequate access to feed in the development phase can reduce follicle development, pituitary hormones [43], oocyte quality [44] and delay puberty [45]. While most farms initiate boar exposure for gilts starting at 140 to 180 days of age, there is still a 60 to 80 day spread in age at puberty, with 10-20% of gilts failing to express estrus even in this time period. The spread and delay in puberty can lead to additional regrouping stress and ineffective use of space. Stressors such as heat, crowding, bullying and anxiety have been suggested to be involved with weak display of estrus in gilts. Compared to sows, gilts have a shorter duration of estrus with an average of 40 hours and a range of 19 to 52 hours [46]. This range in duration of estrus could be affected by stress and housing. Gilt reproductive failure could result from chronic stress associated with grouping, moving, and management of gilts in small or large groups until the time of selection or start of boar exposure.

For puberty induction, gilts can be moved to a boar pen, a specific boar exposure area, or boars can be moved near or into the gilt pen. The acute stressors of regrouping and relocation in combination with boar exposure may actually help induce a synchronous estrus in peri-pubertal gilts. For gilts housed in stalls or pens [18], moving gilts to the boar improved detection of estrus compared to moving the boar to the gilts. It is important to note that literature reviews [47] suggest that the estrus response is reduced when gilts are housed in pens of only 3 compared to housing gilts in larger group sizes [48]. Once gilts are detected in estrus, they may remain in that pen, be relocated to another pen with the same or even different numbers of unfamiliar mature gilts, or may be moved into stalls. However, gilts moved 5 to 15 days after their first or second estrus, show reduced synchrony in the next estrus. Some farms may not relocate gilts until a second heat is detected at which time they will move gilts to a breeding barn and house them in small groups of 3 to 6 gilts, large groups of 20 to 30 gilts, or may move them into stalls. Industry data suggests gilts average 218 days for a heat no service with an entry to service interval of 47 days and subsequent breeding at 264 days of age [49]. Interval from entry to service can range from 0 to more than 51 days. Many farms now choose to synchronize estrus in mature replacement gilts using an approved synthetic progestagen (Matrix®, altrenogest). Effective administration of this product is essential and requires individual administration for 14 consecutive days. This can be administered as a top dress with individual feeding in stalls, but in group housing systems, many choose to dose individuals orally.

Many farms target breeding to occur at second estrus when the gilt reaches 300 lb., 16 to 17 mm backfat, and is older than 200 days of age. At breeding, insemination is expected to occur in the presence of a boar. This procedure can aid in achieving standing heat and subsequent sperm transport after mating, but breeding without a boar present had no detrimental effect on fertility [50]. After insemination, gilts may be relocated once again into new stalls, or regrouped with unfamiliar females in small or large size groups until farrowing [10]. For gilts that will be moved into larger groups with an ESF, a training pen can be essential for the success of the gilts [51]. It is important to note that 14% of all mated gilts will fail to farrow, for reasons that have yet to be determined [39].

Mixing prepubertal gilts. Most existing recommendations suggest that gilts respond positively to acute stressors such as regrouping, relocation and exposure to boars just before the time they reach puberty. The outcome is that a proportion of the gilts will exhibit estrus within 10 days, with additional gilts showing heat over the next 10 to 20 days and 30 to 50 days. However, as previously mentioned, while there are positive effects of this type of stress, some gilts fail to show estrus or display only weak estrus signs. In these cases, it is unclear whether this is a result of stress from aggression and competition for resources.

Mixing cycling gilts. Mixing cycling gilts is a common practice prior to breeding. While many cycling gilts are relocated to a stall, others are identified and moved into a new pen with other cycling gilts. Stress from social aggression could have negative consequences on health, reproduction, and feed intake at critical time periods prior to breeding. However, it has been reported that when gilts are housed in groups of 4, mixing cycling gilts had no detrimental effect on estrus expression within a 5 week period when compared to non-mixed gilt groups [52].

Mixing bred gilts in the first week. van Wettere et al. [53] conducted a study in which gilts were treated with exogenous gonadotropins to stimulate onset of puberty and after their second estrus, mated gilts were moved into stalls or penned in groups of 6 with pre-mating pen mates, or with unfamiliar gilts. Mixing under these conditions on days 3-4 or 8-9 of gestation had no effects on pregnancy rate or number of embryos present on day 26 of gestation. Similarly, no effects on pregnancy rate or embryo number were observed when mixing bred gilts at 4 to 5 days of gestation in groups of four [52] or when mixing gilts in groups of 6 during the first 10 days after breeding [53]. Compared to gilts housed in gestation stalls, those mixed in pens of 5-6 following AI, consumed less feed and lost more backfat during the subsequent lactation and weighed less at weaning. However, these sows weaned a greater percentage of pigs compared to those from stalls. In another study, gilt offspring from gilts that were housed in pens throughout gestation had reduced body weight, lower gain to feed ratios, and greater backfat during the grow-finish phase compared to gilt mothers housed in stalls. However, the gilt mothers housed in pens during gestation had a greater proportion of their offspring reaching puberty by 165 days of age, compared to those gilts from mothers housed in gestation stalls [54].

Mixing bred gilts in the second to third week. Industry reports have long suggested that moving pregnant gilts during implantation is risky. However, mixing bred gilts during this period, in groups of 4, had no effect on pregnancy rate or number of embryos by day 30 [52].

Mixing bred gilts after the fourth week. There is data to suggest that compared to holding gilts in pens of 5-6 throughout gestation, keeping gilts in stalls for the first 30 days of gestation and then moving them into pens for the remainder of gestation, increased the numbers of pigs born alive. Further, the gilts housed in pens throughout gestation consumed less feed and lost more body weight and backfat in lactation. The female offspring of gilts housed in pens throughout gestation displayed decreased gain to feed during the grow-finish phase compared to offspring farrowed by gilts that were housed in individual stalls until day 30 of gestation and then group housed in pens for the remainder of gestation [54]. Data also suggests that mixing pregnant gilts after day 30 of gestation reduced lameness and lesions scores, but had no effect on number of embryos. Although not commonly reported, mixing gilts in pairs in the last third of gestation increased the hormonal stress response [55], but no subsequent measurements were obtained on farrowing and litter size, lactation performance or longevity.

Forming weaned sow groups in breeding and gestation

Introduction to housing weaned sows. Housing sows in stalls throughout gestation has been shown to result in the highest farrowing rates, longevity and welfare compared to sows mixed at various days following breeding [1, 56]. Keeping sows in stalls throughout gestation has been an effective method of management with farrowing rates (84%), litter sizes (12 total born) and sows bred within 7 days of weaning (90%), all continuing to show improvements each year [57]. Boar exposure after weaning is an important factor for inducing follicle development and advancing post-weaning estrus [58]. Estrus detection efficiency can be reduced by housing the boar too close, but sow housing in stalls or pens of four did not alter detection efficiency [13]. While some studies in gilts have suggested that estrus detection is improved in group housing systems where direct physical boar contact is allowed, at this time, no definitive studies have proven this for weaned sows.

Since most farms utilize farrowing stalls to maximize live born pigs and number of pigs weaned, a decision can be made to form sow groups at weaning or at a later time following initial movement into a stall. However it is of interest to note that some farms in Europe have successfully moved to small group farrowing systems [59]. In the U.S. however, most commercial farms wean sows into stalls in the "breeding snake" (sets of contiguous gestation stalls). This involves relocating a group of newly weaned sows to a location within a breeding barn vacated by a sow group just moved into the farrowing house. In this system, sows that fail to express estrus do not stay in the snake and are removed. Spaces are also maintained within the snake to accommodate bred replacement gilts and recycle sows that will fill the open spaces in the breeding group. There are options where the bred replacement gilts and recycle sows may remain until moved into farrowing. Most recommendations have suggested pregnant females not be moved, except in the first week or until after day 35 of gestation. From time of weaning through gestation, it appears that stress and feed intake disruptions in the breeding and gestation phases can affect sow reproduction. Following weaning, the follicle phase begins and nutrient intake may be important for hormone production, estrus expression and ovulation. In early gestation, proper feed intake is important for re-establishing body condition, hormone levels, early embryo survival and rapid development. In mid- to late-gestation, feed intake is a factor related to fetal growth, mammary development, and establishment of body reserves for lactation [60]. It is likely that the stress associated with aggression and competition for feed and resources among sows in group housing can alter individual feed intake in certain sows.

Forming sow groups immediately after weaning. This process involves weaning sows from farrowing stalls directly into a group pen. The options with this system are whether to group females by size or parity and what size group to create. Compared to housing sows in stalls, the overall proportion of animals expressing estrus when mixed after weaning was not different [13], but estrus was delayed by grouping by 10 hours [61]. A review of the effects of mixing [62] reported a study with large groups that were weaned into pens or held in stalls for 4 weeks until mixing. The results showed that weaning into groups reduced litter size but did not affect conception rate compared to mixing after 4 weeks. Simulated stress in weaned sows by injection of ACTH during the proestrus period, resulted in an increase in cortisol, and had detrimental effects on follicle development, duration of estrus, progesterone, oviductal environment, and oocyte and sperm transport [63]. Data suggests that in group sow housing, number of lesions and reduced feed intake are associated with reduced pregnancy rate and litter size [64]. Mixing sows after weaning was also reported to reduce day 28 pregnancy rates compared to sows housed in stalls. The investigators noted this failure appeared to be related to an extended wean to estrus interval [65]. These studies seem to conflict, but it would appear that mixing after weaning does have risk for a detrimental and consistent effect on delay of estrus which may alter optimal AI timing relative to onset of estrus and time of ovulation and potentially impact litter size [66, 67].

Forming sow groups after the first week following breeding. In the Netherlands, new directives suggest that sows should be in groups by four days following AI. An industry report from a 1000-sow farm applying this regimen with 50 sows per pen where sows were fed using an ESF, reported an average litter size of 14.4 with 2.48 litters per sow per year [51]. The author noted that with this type of system, a minimal number of stalls are needed as the sows stay in stalls for only a few days. A research study using dynamic mixing of 50 sows at day 5 after breeding with another group of 50 sows, revealed no effects on farrowing rate, litter size or longevity, although injury scores were greater than the static group in the 2 weeks measured after mixing [68]. Additional data shows that sows mixed in groups of 15 at day 2 or day 7, showed no detrimental effects on farrowing rate or litter size [69]. A review of studies examining day of mixing showed the greatest farrowing rates and litter sizes for sows that were mixed in groups in the first week compared to later weeks [70]. One study observed that for sows mixed 2 to 4 days after breeding in groups of 30 to 60 sows where sows were fed with an ESF, farrowing rates were improved compared to sows housed in stalls [71]. A recent industry report suggests that forming sow groups in commercial production systems in the first week when sows are no longer in standing heat can work well [72].

However, a review of experiments with mixing sows in the first 10 days after breeding revealed higher return rates in multiple studies, and lower litter size in some studies when compared to mixing sows after the 10 day interval from mating or at 4 weeks following breeding [62]. To support these observations, a recent experiment that tested treatment groups of 58 sows mixed at days 3 to 7 following AI to those housed in stalls or mixed after the fourth week of gestation, showed reduced pregnancy and farrowing rates. Longevity was also reduced in this group compared to sows in stalls but did not differ from sows mixed at later times [56]. Welfare measures were also classified within the first 12 days after mixing and the remaining days until farrowing. Fighting, cortisol, lameness, body and vulva lesions all increased soon after mixing. Lameness, leg inflammation and vulva lesions all increased in the period until farrowing and while body lesions decreased, they were still greater than sows in stalls.

These studies suggest variation in responses among experiments and industry reports. Two controlled studies did not observe a detrimental effect on reproduction while one showed a reduction in fertility and longevity. Two of the studies reported reduced animal welfare when mixing at in the first week after breeding and this may be an important consideration. While the industry reports noted reproductive fertility was similar to other stall gestation units, controlled experiments were not performed and direct comparisons are speculative. Further, industry reports did not include any assessments for animal welfare. Mixing in the first week after breeding, should be approached by evaluating the published research study methods and the measures evaluated to determine the associated risks if this method of group formation is chosen, and management plans can be adapted to the expected outcomes.

Forming sow groups in the second to fourth week. Most recommendations strongly suggest avoiding the mixing of sows in the second to fourth week of gestation due to the potential for embryonic loss and pregnancy failure. However, the data are controversial concerning effects on reproduction. This may be important as producers may at some time, be forced to mix gilts and sows during this time period due to space and animal flow constraints. Studies suggest that stress associated with feed restriction or elevated cortisol at implantation had no measurable effect on pregnancy rate or number of healthy embryos at day 30 of gestation [73]. Stress from dynamic sow group mixing, with formation of 50-sow groups at day 5, and then again with another group of 50 sows 14 days later (day 21 of gestation), had no effect on reproductive measures [68]. Other research studies also showed that forming groups of sows at days 14 or 21 had no detrimental impact on farrowing rate or litter size [69].

In contrast to the previous studies, a review of studies that evaluated sow mixing days with groups of 15 sows, indicated lower reproductive performance in sows mixed at 14 to 21 days of gestation compared to those sows mixed in the first week [70]. A recent study that mixed sows at days 14 to 17 of gestation into groups of 58 sows with an ESF, reported conception rates were reduced compared to sows mixed after the fourth week and those in stalls, but farrowing rates and litter sizes did not differ. In this same study, longevity was reduced in the d 14 to 17 mixed sows compared to sows in stalls. Welfare measures showed a lower number of fights in the first 24 h after mixing compared to sows mixed in the first and after the fourth week. Welfare measures included increased cortisol, lameness, body, and vulva lesions in the first 12 days after mixing compared to sows in stalls. Lameness, and lesions were greater in the remaining period until farrowing compared to sows in stalls [56]. Arey and Edwards [62] reviewed a study where sows were mixed in groups of 3 on day 11 of gestation and reported that cortisol increased in the dominant sow, and even more in the submissive sow, but not in the middle ranking sow. Despite this observation, there was no effect on reproductive hormones. Other studies have also not shown a relationship of social rank to reproductive fertility.

Collectively, the available data on mixing sows at days 14 to 21 of gestation provide limited evidence for significant reproductive failure. However, since group size, pen design, feeding method, and several other factors could interact to impact fertility, attention to the details of the reported systems tested and the measures evaluated for reproduction and welfare should help producers determine the risks and develop management strategies to minimize these when mixing sows in this stage.

Forming sow groups after the fourth and up to the seventh week.
Most recommendations for forming sow groups suggest waiting until after the 4th week following confirmation of pregnancy before mixing. This is a practical and effective system and results in sow performance similar to sows that are housed in stalls [72] and with large groups using an ESF [74]. In a review of mixing sows during days 28 to 50 of gestation [1], it was reported that reproductive performance was similar to that for sows housed in stalls. A recent study in which sows were mixed after day 35 in groups of 58 using an ESF showed farrowing rates and longevity were similar to sows in stalls and sows mixed at day 14, but better than sows mixed in the first week [56]. However, a study comparing day of mixing sows in groups of 15 sows, showed no effect compared to earlier days at mixing [69].

The EU has allowed the use of the gestation stall for the first 30 days following mating. However, some countries are in the process of phasing out stall use altogether. From a production perspective, use of gestation stalls for the 4- to 5-week period following breeding has advantages in reducing sow stress, improved reproductive management among sows, and allows individual sow feeding for those that lost excessive body condition in lactation or have become overly conditioned. Thin sows can be fed more and sows with excess body condition can be fed less. Pregnancy diagnosis among sows in stalls using an ultrasound machine from days 28 to 35 is rapid and accurate as technicians can quickly diagnose sows as pregnant or open [75]. In contrast, in group pens, pregnancy diagnosis with ultrasound will require additional time as the technician must find the sow and, obtain a good image whether the sow is stationary or moving, and mark the sow.

Although the main focus of day of mixing has always been on reproductive performance, only one of the studies evaluated the effect of mixing after the fourth week of gestation for reproduction and welfare. Hopgood et al. [56] compared the welfare of sows mixed into groups of 58 sows after the fourth week to sows mixed in the first, the second to third week, and to those maintained in stalls. These data showed that the number of fights in the first 24 h after mixing was greater than those mixed in the second to third week and similar to those mixed in the first week. Welfare measures in the first 12 days after mixing showed increased cortisol, lameness, body, and vulva lesions compared to sows in stalls. In the remaining period until farrowing, lameness, body and vulva lesions all declined but were still greater than sows in stalls.

Forming sow groups after the seventh week.
While this is often not reported, it is possible that this practice may be needed for production flexibility. It has been reported that mixing sows in groups of 50 at days 65 to 70 of gestation resulted in increased sow aggression and cortisol, but had no effect on sow fertility compared sows that remained in stalls [76].

Handling fallouts, open sows and gilts
Some stalls or pen space may need to be designated for animals that do not maintain pregnancy or recycle following breeding. For sows that are open or express estrus in stalls, they may remain in place or be moved to a new area with the current breeding group. For those diagnosed as open in pens, a decision must be made whether to breed the female in that pen and let her remain with that group or to remove her and place her in another stall or pen. If she remains with the existing pen-group, she will have to be relocated into a stall or pen, or mixed with an unfamiliar group in late gestation when her contemporary group moves into farrowing. If she is pulled out of the pen and moved into a stall, she will have to be re-grouped once again.

Suggested mixing strategies to optimize reproduction and welfare

- Avoid re-mixing females once mixed
- Mix by parity or size
- Group females by size using a system of 3 groups: 1) thin; 2) moderate; and 3) heavy sows.
- Use “mixing” pens for gilts, where 3 or more gilts or sows can be mixed in a sub-group for 2 to 3 days before addition to the larger group of any size. The mixing pen should have excess space to allow flight.
- Consider penning new gilt/sow entries into a pen within the larger pen. This can be effective as sows in the large pen do not consider this their space.
- House replacement gilts next to sows to help develop their social skills and familiarity [70].
- Train gilts to use ESF stations before addition into the breeding herd.
- Provide adequate floor space in group pens and allow extra fleeing space
- Mixing in the evening may help reduce aggression
- Although industry recommendations include adding a mature boar to reduce aggressive interactions after sow mixing, controlled research studies have shown no beneficial effect [77] in groups of 15 sows, when using physical or fence-line boar contact.
- Add pen barriers such as partial walls and visual barriers
- Feed multiple times each day especially in the first few days after mixing
- Overfeed at mixing and after mixing to limit competition

- Increase fiber in diet to increase satiation
- Avoid competitive systems such as floor feeding
- Small groups of 6 to 10 sows should remain static to avoid continual disruption of social order while larger pens can use dynamic flow.
- Dynamic grouping involving addition and removal of sows each week can be aided by allowing the formation of sub-groups within the pen by providing separate lying areas for each sub-group [78].
- The larger the group, the more hierarchal positions may need to be established [62].

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