

# Chapter 11: Swine

## FACILITIES AND ENVIRONMENT

Swine readily adapt to a variety of production systems (Pork Industry Handbooks, undated and 1978 to present; MWPS, 1983; Baxter, 1984; Whittemore, 1993). The level of management applied should be commensurate with the requirements of the production system to assure pig comfort. In certain systems, more stockmanship may be necessary to meet the needs of pigs. Specific attention should be paid to management of effective environmental temperature (Table 11-1), prevention of lengthy exposure to sun, ventilation, vapor pressure, floor condition, area per pig, manure management, quantity and quality of feed and water, and prevention of disease and distress.

A predictable daily management routine allows pigs to develop a routine of their own. Animal care personnel should plan for swine management under climatic extremes and emergency conditions; personnel should be able to provide appropriate husbandry to minimize environmental stressors and animal distress. Animal care staff should be familiar with the behavior of normal pigs and of pigs experiencing stress or reduced well-being so that timely intervention can be applied.

Attention should be given to pig dunging and resting preferences during both the design phase and the daily operation of swine facilities. Movement of manure and urine between pens should be minimized. Similarly, animal care personnel should take necessary precautions to prevent transmission of pathogens between pens and between facilities, even at the same location.

### Microenvironment

The microenvironment consists of all factors external to the animal, which includes thermal environment (air temperature, air movement, and moisture); physical environment (pens, walls, and floors); social environment; and microbial environment. The thermal environment is probably one of the most difficult components to manage at times because pigs of different ages have different thermal requirements. Hence, it is important that pigs be managed based on their thermal needs during each stage of production. The lower critical temperature for younger pigs is higher than that of older

pigs, thus a higher effective environmental temperature is required. The thermal environment should be managed so that the microenvironment is maintained as close to the zone of thermal neutrality for the age of the pig being housed (Table 11-1).

Ventilation goals differ with changing seasons. A properly ventilated building is free of drafts and provides clean, fresh air without chilling the pigs. A minimal ventilation rate should be achieved in the winter, with air exchange being at its lowest rate but still efficient enough to remove moisture. Excessive moisture (>80%) provides a vehicle for microorganisms, wets the pigs, and damages insulation. As a rule of thumb, ventilation rate in winter should not fall below 6 air changes per hour. In conjunction with minimum ventilation rate, relative humidity and CO<sub>2</sub> are important measures of air quality; one or both of these factors should be considered when controlling ventilation rate (Kephart, 2007). Maximal ventilation rate should be achieved in the summer so that the ventilation system keeps air moving to remove animal heat (and will remove moisture as well).

### Lighting

The domestic pig is less sensitive to its photic environment than are some other species. Data are conflicting as to whether light can manipulate reproduction, physiology, and performance of pigs. However, current data indicate that photoperiod can influence productivity and various physiological measures of sows and piglets (Bruininx et al., 2002; Halli et al., 2006; Niekamp et al., 2006, 2007). In the wild, swine do not depend on vision as much as on other sensory systems (Kilgour, 1985), but if pigs are able to control the photoperiod for themselves, pigs prefer some light and some dark every hour of the day and night (Baldwin and Meese, 1977); their apparent light-dark cycle preference is not similar to any natural situation.

Photoperiod manipulation may influence pig immune status (Niekamp et al., 2006, 2007), but data on photoperiodic effects on pig biology are contradictory or unclear. Other factors such as weaning age, light intensity, and other physiological factors may impact the effects of photoperiod on growing; thus, no par-

**Table 11-1.** Recommended thermal conditions for swine used in agricultural research and teaching<sup>1</sup>

	Preferred range <sup>2</sup>	Lower extreme <sup>3</sup>	Upper extreme <sup>4</sup>
	15 to 26°C (59 to 79°F) for sow	15°C (60°F) sow area	32°C (90°F) for sow
Lactating sow and litter	32°C (90°F) minimum creep area for piglets	25°C (77°F) creep area	No practical upper limit for piglets
Prenursery, 3 to 15 kg (7 to 33 lb)	26 to 32°C (79 to 90°F)	15°C (59°F)	35°C (95°F)
Nursery, 15 to 35 kg (33 to 77 lb)	18 to 26°C (64 to 79°F)	5°C (41°F)	35°C (95°F)
Growing, 35 to 70 kg (77 to 154 lb)	15 to 25°C (59 to 77°F)	-5°C (23°F)	35°C (95°F)
Finishing, 70 to 100 kg (154 to 220 lb)	10 to 25°C (50 to 77°F)	-20°C (4°F)	35°C (95°F)
Sow or boar, >100 kg (>220 lb)	10 to 25°C (50 to 77°F)	-20°C (4°F)	32°C (90°F)

<sup>1</sup>Although recommended air temperatures are given in this table, performance measures would more appropriately determine pig thermal comfort. When pigs are in a comfortable thermal setting, they will rest comfortably, not shiver or pile on one another, not have an elevated respiratory rate, and will generally rest touching other pigs. Some individual pigs may prefer to rest alone. Piling or spreading out widely may indicate the environment is too cold or too warm, respectively. Pig behavioral thermoregulatory behaviors are better indicators of the appropriate air temperature than a thermometer.

<sup>2</sup>Based on values given by NRC (1981), DeShazer and Overhults (1982), Curtis (1985), and Hahn (1985).

<sup>3</sup>Values represent lower extremes in air temperature when pigs are held in groups. Bedding is recommended when air temperature approaches the lower extreme.

<sup>4</sup>Except for brief periods above these air temperatures, cooling should be provided by means such as evaporatively cooled air for growing pigs or a water drip for lactating sows.

ticular daily photoperiod is necessary for growing pigs (Berger, 1980). Developing breeding animals may benefit from long-day photoperiod (e.g., 16 h of light and 8 h of dark; Zimmerman et al., 1980; Wheelhouse and Hacker, 1982). Gilts managed on long days had higher basal concentrations of luteinizing hormone (LH) than did those on short days. Photoperiod had no effect on changes in LH frequency in prepubertal gilts (Halli et al., 2006). Photoperiod in late gestation can also influence endocrine and performance measures of the gestating sow and her offspring (Niekamp et al., 2006). Lactating sows responded positively to 16 h of light and 8 h of darkness, resulting in enhanced piglet performance, and some studies have reported that these sows may return to estrus sooner (Mabry et al., 1982, 1983; Stevenson et al., 1983) but this effect was not observed in a subsequent study using more replications (McGlone et al., 1988). Light regimens oscillating from 9 to 16 h of light on a daily basis had no effect on boar semen quality or fertility, prolificacy, or libido (Rivera et al., 2006; Sancho et al., 2006). Although there are times that a specific light cycle may be a beneficial management tool for pigs, the photoperiod selected may depend on the sex, age, and stage of production of the animal. Changing the photoperiod may affect pig reproduction in some ways, but changes in photoperiod have not been linked to sow or boar well-being.

## FEED AND WATER

Pigs should be observed and their well-being assessed at least twice each day. Feeders and waterers must be checked to be sure they are functional. Design and position of feeders and waterers should enable the pigs easy access while minimizing feed waste. Feeders or feeding places should be free from manure, urine, and other contaminants. Pigs may be fed from the floor as long as the surface is dry and clean and individual feed consumption is not limited by social competition. A water medicator may be used for management of enteric infections. When feed is delivered to animal houses and to individual pens, care should be taken to minimize dust. Pigs should be fed to meet or to exceed nutrient requirements as determined by the NRC (1998) for their particular stage of the life cycle. Ad libitum access to water should be provided and special care should be taken to ensure that water devices are accessible for each size of pig.

## HUSBANDRY

### Social Environment

Young pigs and sows are by nature social animals. In fact, sows are often found in groups in nature, except before and after parturition when they seek isolation.

Feral boars are usually solitary animals, except during breeding season.

Young pigs show behavioral and physiological signs of stress when held in complete isolation from other pigs. The precise relationship between group size and pig performance is neither predictable nor clear (Livingston et al., 1969; Patterson, 1985). Growing pigs are commonly found in group sizes from 2 to 30 pigs per pen, but groups of hundreds or even thousands of pigs per pen have become more common, especially in commercial wean-to-finish systems. In social groups, the level of social stress (fighting) is high and productivity may decline but once social status is established the group often becomes relatively stable. In some cases, adult pigs housed individually may experience less stress than growing pigs. Agricultural research that proposes to house pigs individually or in isolation from other swine should be justified and approved by the IACUC.

### **Farrowing Systems**

**Sow Management.** Before preparturient sows are moved into indoor farrowing environment, the environment should be cleaned, disinfected, and dried. Outdoor farrowing environments should be treated as described previously (if possible) or the outdoor area should be exposed to sunlight for several days before moving a new group of farrowing sows to the area. Sows may be treated to eliminate internal and external parasites before entering the farrowing area if parasites are present. Laxative additives or a specially formulated diet may be fed before and after parturition to minimize constipation.

The presence of a caretaker during farrowing is not mandatory (Lawrence et al., 1997), but the presence of an individual during farrowing may improve neonatal survival (Friendship et al., 1986; Holyoake et al., 1995).

Behavioral thermoregulation of sows may include postural changes; for example, extension of body contact with a cooler surface, shade seeking, minimizing contact with other animals, or open-mouth breathing (Curtis, 1983; Blackshaw et al., 1994). Sows have a large body weight but a low body surface-to-mass ratio; therefore, it is more difficult for sows to dissipate internal heat (Hansen and Vestergaard, 1984). During hot weather, especially when humidity is high [daily maximum temperature above 29°C (>85°F)], sows may need to be zone cooled. Sows may be cooled by misters, sprinklers (accomplished by dripping water directly on the sow's shoulders), evaporative coolers (Heard et al., 1986), and ventilation fans (McGlone et al., 1988) or by providing directed currents of air (snout coolers; Bull et al., 1997). Effective thermoregulatory methods that can be used in an extensive system include enabling sows to wet themselves with water or mud.

### **Confinement Before Farrowing**

Jensen (1988) proposed that maternal behavior can be divided into 6 distinct parts: 1) isolation and nest site seeking, 2) nest building, 3) farrowing, 4) nest occupation, 5) social integration, and 6) weaning. Isolation and nest-site seeking behavior that occurs 48 to 24 h before the birth of the first piglet has been observed in wild, feral, and domestic sows outdoors. The sow often leaves the social group and seeks isolation. Therefore, some degree of confinement of the periparturient sow is both necessary and preferred by sows (Phillips et al., 1991). Even in extensive housing systems, sows may be provided with a small hut or pen in which they can be confined and excluded from their group mates.

**Farrowing Systems.** A wide variety of options is available for housing sows during farrowing and lactation ranging from conventional stalls to outdoor paddocks (Collins et al., 1987; Thornton, 1988; McGlone and Morrow-Tesch, 1990; Edwards, 1995; McGlone et al., 1995; McGlone and Hicks, 2000). Farrowing systems should meet the performance standards of minimizing preweaning piglet mortality, providing thermal comfort for sow and piglets (which may require zone heating/cooling), providing a sanitary environment for sows and piglet, and accommodating normal sow and piglet behaviors where possible. Restricting sow movements in the well-designed farrowing stall will improve piglet survival, and this trade-off should be carefully considered in the selection of any farrowing system.

**Farrowing Stall.** To reduce piglet injury and protect animal care personnel from overly aggressive periparturient sows, indoor sows may be confined in farrowing stalls or free stalls from d 109 of gestation until the piglets are weaned (Curtis, 1995). A variety of farrowing stalls are available. The standard farrowing stall is usually a tubular metal construction fixed within a pen of about 2.2 m × 1.5 m (7.2 ft × 4.9 ft), with recommended dimensions of around 2.2 m long, 0.6 m wide, and 1.0 m high (7.2 ft long, 1.97 ft wide, and 3.28 ft high). If the farrowing stall length can be adjusted, it should be adjusted based on the body length of the sow. Sows should be able to rest comfortably in the farrowing stall without the need for her head to rest on a feeder due to inadequate length of stall.

Most farrowing stall floors are slatted or perforated so that sows and piglets are effectively and quickly separated from their excreta and the environment dries quickly. Acceptable types of slatted floors include perforated metal, woven metal, plastic-coated metal, metal bars, fiberglass, concrete, and combinations of materials. The floor surface should be nonabrasive, nonporous, and not slippery (Fritschen and Muehling, 1984). Slots between slats should be wider behind the sow [usually 2.5 cm (1 in)] to allow passage of excreta. These wider openings may be covered during parturition to enable piglets to walk easily. In addition, narrower perforations or slots prevent piglets from getting their feet caught in the floor openings. Rubber mats may be pro-

vided in the creep area for the first few weeks. Floor materials should be free of exposed or projecting materials to avoid injury to the leg, foot, or hoof. Bedding should be provided for farrowing crates equipped with solid floors. Flooring materials should meet the performance requirements that 1) animals are supported and not slippery, 2) slatted floors should not trap feet and legs, 3) slats should provide a clean environment by separating the manure from the animals, 4) floors in combination with other features of the room should provide thermal comfort, and 5) floors must be able to be sanitized or to provide a clean surface. A creep area is usually set to the side or front of the stall with a heat source that provides a warm lying area for the litter. Good disease management practice dictates that all sows should enter and leave the farrowing accommodation at the same time (all-in, all-out) and thus the number of farrowing places in a room should be related to the number of sows that are due to farrow in a given cycle. The partitions between the pens should be high enough to prevent piglets from escaping.

**Indoor Farrowing Pens.** Farrowing pens may be used for sows and litters only if preweaning mortality is not increased relative to preweaning mortality in well-managed farrowing crates. Acceptable indoor pen designs include ellipsoid farrowing crates (Lou and Hurnik, 1994), modified triangular farrowing crates (McGlone and Blecha, 1987; Heckt et al., 1988), rectangular pens with side rails that allow piglet escape (McGlone and Blecha, 1987; Blackshaw et al., 1994), and farrowing pens with sloped floors or walls (McGlone and Morrow-Tesch, 1990; Cronin et al., 1996; Marchant-Forde, 2002). Turn-around systems are similar to conventional stalls, in that they are made out of tubular metal and the system incorporates a piglet creep area. These systems may be installed on a fully slatted floor for hygiene reasons.

Heated creep areas are used when the farrowing room is zone heated or cooled. The creep area may be either in one corner, along one of the pen short sides or centrally placed in pens that are divided into nesting and dunging areas. Some systems are still straw-based, but open pens have been developed with fully or partly slatted floors (Heckt et al., 1988; Johnson and Marchant-Forde, 2008).

**Farrowing Huts.** As with indoor farrowing pens, some outdoor farrowing huts provide acceptable levels of preweaning mortality. Several farrowing hut designs are available made from wood or plastic including A-frames, steel English-style arcs, and plastic and plywood models. Each hut differs in shape; for example, the A-frame is taller and triangle shaped (Penner et al., 1996; Honeyman et al., 1998a). For all types, some versions have a solid plywood floor and others have no floor. In both cases, it is common to use large amounts of straw bedding or other material. There is no heated creep area and no water supply for the sow or her litter in many well-managed farrowing huts. Some arcs in-

corporate rails to help prevent piglet crushing, whereas others do not have inside rails. Some farrowing huts may have insulation to reduce extremes of temperature, although the benefits of insulation have been questioned in controlled studies (Edwards and Furniss, 1988; Johnson and McGlone, 2003).

Fenders can be fixed onto the front of farrowing huts to help keep the piglets close to the farrowing hut, keep the straw in the huts longer, and allow unrestricted movement of the sow (Honeyman et al., 1998b; Johnson and McGlone, 2003). Fender design may influence the length of time that piglets are confined to the hut and the work efficiency and safety for the stockperson carrying out routine tasks (i.e., litter processing; Johnson and McGlone, 2003).

Sows kept outdoors should be observed regularly; bedding should be provided unless the thermal environment is adequate, and fences should be sturdy and well constructed. Electrified wire may be used. Proper health care for sows and piglets should be provided, and feces and urine should be removed from such systems as the need arises. Sows and litters kept outdoors should be rotated among pastures to avoid accumulation of pathogens and parasites. The farrowing huts or pens should be cleaned and disinfected before each use. If sows farrow outdoors, appropriate sanitation procedures (e.g., moving huts and burning bedding) should be followed to ensure a clean farrowing environment. When supplemental zone heating is not provided, farrowing houses on pasture and pens in central farrowing houses should be bedded with a suitable material such as straw. Bedding should be kept reasonably dry by the addition of more bedding material and by partial removal of soiled bedding at regular intervals as needed.

**Litter Management.** Piglets require special attention because they are born with low body reserves of energy and immunoglobulins, thermoregulate poorly, and are vulnerable to being crushed. Until weaning, piglets should be provided with an area that is warm, dry, draft-free, and zone heated, and piglets should be protected from being crushed or injured by the sow.

The lower critical temperature of the piglet is about 35°C (95°F) at birth. However, the entire space in the house should not be heated to an air temperature approaching the lower critical temperature of the piglets because the sow will become heat-stressed. Zone heating, zone cooling, or both, should be provided to meet the disparate thermal needs of the sow and piglets.

Any of the following procedures may be performed on piglets within a few days after birth: navel disinfected (if farrowing was attended); needle teeth trimmed with a disinfected sharp device; tail trimmed to no less than 2.5 cm (1 in) from the body with a disinfected device (if piglets are to be raised indoors); supplemental iron injected (if piglets are to be nursed indoors); and individual identification made (usually ear notches).

## Nursery Systems

Weaning pigs is a common stressful event that involves sudden change in social and environmental conditions and a change in diet. Thus, weaning at night may be less stressful than weaning during the early morning (Ogunbameru et al., 1992); however, this is often not practical. Typically, nursery systems have included housing and management arrangements for newly weaned pigs until 8 or 9 wk of age, but it is now more common to wean pigs directly into a wean-to-finish building.

Piglets may be weaned at any age, but the younger the piglets are at weaning, the greater is the need for specialized facilities and care, a high degree of sanitation, and high-quality diets (Lecce, 1986; Owen et al., 1995). Segregated early weaning is a production practice that has been implemented to reduce the incidence of disease and to improve pig health and well-being in herds with chronic disease. In a segregated early weaning system, piglets are weaned at 10 to 20 d of age and then transported to a facility that is geographically separated from other swine facilities (Dewey, 1995). This technology reduces the transfer of disease microorganisms from sows to nursery pigs by removing piglets from the sow before passive immunity decreases and sow can infect her offspring. Segregated early weaning is less effective for some diseases, but works well for others. However, segregated early weaning is a management tool used from time to time, not a routine, ongoing management practice.

The lower critical temperature of a 4-wk-old piglet (once it is eating at the rate of approximately 3 to 3.5 times thermoneutral maintenance) is around 26°C (79°F; Table 11-1); therefore, nurseries should be able to meet the ambient temperature needs of the weaned pig, which may require (but not always) supplemental heating equipment, which may include heat lamps, mats, or bedding. When piglets continue suckling (and thus obtaining heat from) the sow beyond 3 wk of age, or when deep bedding is used to create a microenvironment in the range of thermoneutrality, then supplemental heat may not be required in a nursery building. The key is to provide an environment that provides thermal comfort for the pigs by meeting their needs for an appropriate effective environmental temperature.

Environmental management is critical to the success of wean-to-finish buildings. Ventilation is similar to typical finishing facilities but it must be possible to adjust fans for minimum ventilation for the newly weaned pigs. Zone heating is recommended to meet the needs of the young pig. Pig behavioral thermoregulation should be used to determine if the temperature is too high or too low.

In addition to having supplemental heat, nursery houses should be maintained at a higher degree of sanitation than is required for older pigs. Nurseries should be operated on an all-in, all-out basis, and the facility should be cleaned, disinfected, and dried thoroughly

between groups of pigs. Room air should be warmed to the proper environmental temperature before pigs enter the building.

Weaned pigs should be self-fed a nutritionally complete and balanced diet unless the experimental protocol dictates otherwise (NRC, 1998). Feeding space should be provided that allows all pigs to eat to their appetite over a 24-h period. Four or more pigs may share a feeder space as long as feed intake is not limited. Feeders that supply water as a part of the feeder (wet/dry feeder) may support more pigs per feeder space. Pigs should be provided ad libitum access daily to clean water. One watering device is needed per 10 to 20 pigs with at least 2 watering devices per pen located far enough apart that one pig cannot dominate both. The height of the waterer should be set so that pigs can readily drink from the watering device. When possible, pigs should be allocated to pens based on body weight and age to facilitate effective feeding and water management (Patience et al., 2004).

The general nature of pig growth is rapid early growth followed by a leveling-off of growth rate. Groups of pigs have different space requirements than individually housed pigs. The bodies of pigs require a certain amount of space called the *occupied space*, and the space in the pen that remains is the *free space*. The amount of space a pig occupies depends on posture and behavior. The amount of unused or free space increases with increase in group size, but research has shown that if all the free space is removed, reduced feed intake and reduced body weight gain will result. McGlone and Newby (1994) showed that removal of 50% of the free space has no effect on pig performance, but removal of more than 50% results in a slow-down in average daily gain. Space needs for pigs in outdoor lots should be based on local performance standards, not on hard-and-fast numbers. Floor area recommendations are in Table 11-2.

Slatted floors are common in nurseries as well as wean-to-finish buildings. The flooring material may be similar to that in farrowing crate units. Pens with solid floors should be bedded with straw or a material with similar thermal and absorbent properties. If partly slatted floors are used, the waterer should be located over the slots.

## Growing and Finishing Systems

The growing-finishing stage refers to pigs from 8 or 9 wk of age to market age of about 20 to 25 wk and finished body weights between 114 and 136 kg (250 to 300 lb). The management of growing and finishing pigs differs from that of weaning pigs in that a lower standard of sanitation is required, units may be run with a continuous flow of pigs, and older pigs can tolerate a much wider range of environmental temperature than younger pigs (Table 11-1). Although growing-finishing systems may use a continuous flow of pigs, an all-in, all-out system is preferred. Restricting the number of

**Table 11-2.** Minimum floor area recommendations for the animal zone for swine used in agricultural research and teaching<sup>1</sup>

Stage of production	Individual pigs (per pig)		Groups of pigs (per pig) <sup>2</sup>	
	(m <sup>2</sup> )	(ft <sup>2</sup> )	(m <sup>2</sup> )	(ft <sup>2</sup> )
Litter and lactating sow, pen	3.15	35	—	—
Litter and lactating sow, sow portion of crate	1.26	14	—	—
Nursery, 3 to 27 kg (7 to 60 lb) of BW	0.54	6	0.16–0.37	1.7–4.0
Growing, 27 to 57 kg (60 to 125 lb) of BW	0.90	10	0.37–0.56	4.0–6.0
Finishing, 57 to 104 kg (125 to 230 lb) of BW	1.26	14	0.56–0.74	6.0–8.0
Late finishing, 105 to 125 kg (231 to 275 lb) of BW	1.26	14	0.74–0.84	8.0–9.0
Mature adults <sup>3</sup>	1.26	14	1.49	16.0

<sup>1</sup>Floor area guidelines here are general recommendations. The minimum space needs for growing pigs follows the general formula of area =  $0.33 \times \text{BW}^{0.67}$ , where BW is in kilograms and area is in square meters. Pigs given adequate floor space will lie comfortably without needing to raise their head while resting or constrict their body during normal postures.

<sup>2</sup>Group area allowances for growing pigs range from starting to ending BW in each phase. The needed floor area per pig decreases as group size increases (McGlone and Newby, 1994). The data presented here are for typical group sizes from 5 to 20 pigs per pen. For small group sizes (2 to 4 pigs), the pens should be longer than the body length of the largest pig in the pen.

<sup>3</sup>Stall size minimum width should be 56 cm (22 in), and minimum length should be 2.2 m (7 ft). Young adult females may be housed in stalls of 2 m (6.5 ft) length.

times pigs are moved or mixed is desirable because mixing pigs generally results in aggression, increases health problems, and causes performance setbacks.

Typically, growing-finishing pens are rectangular and contain 20 to 1,000 pigs per pen (or more). Up to 10 pigs may share a feeder space, and up to 20 pigs may share a waterer in the grow-finish phase. In most situations, pigs should have ad libitum access to water. There are systems that provide water in fixed watering bouts and some systems provide water only when feed is delivered. When water is available in intervals, it should remain on for at least 30 to 45 min at one time (McGlone, 2003). Water should always be available when pigs are feeding. The height of the waterer should be adjusted appropriately as pigs grow. Specialized feeding and watering equipment may accommodate different pig densities.

Penning materials should be sturdier than those used in nurseries. Flooring can be solid, solid and bedded, partly slatted, or totally slatted. Solid floors should be sloped (e.g., 1 to 3%) to allow water and manure to flow to a drain or a pit. Slatted floors need not be sloped. Although many flooring materials are acceptable, concrete slats are recommended for slatted floors. Concrete slats should allow support of pig's feet and allow manure to fall easily between the slots. Edges of the slats should be rounded to preclude foot-claw injuries, and sharp edges should be avoided. Open flush gutter systems are acceptable, but risk of contamination between pens is significant.

Floor-space allowance is a complex issue within swine production. Floor area recommendations are in Table 11-2. Traditional space requirements were established with relatively small group sizes, with larger group sizes, there is a greater amount of shared, unused, or free space. Thus,  $0.65 \text{ m}^2/\text{pig}$  ( $7 \text{ ft}^2$ ) is adequate for main-

tenance of economical pig growth (Brumm and Dahlquist, 1997). Pigs up to 250 lb of body weight and in small groups sizes (<20) require  $0.74 \text{ m}^2/\text{pig}$  ( $8 \text{ ft}^2$ ), and larger group sizes, especially those over 50 pigs/pen and up to 300 lb may need only  $0.74 \text{ m}^2/\text{pig}$  ( $8 \text{ ft}^2$ ) as well. Floor space allowance may be determined using the following equation [ $A = k \times \text{BW}^{0.667}$ , where A = floor space allowance, and k = represents a space allowance coefficient], which converts pig body weight into a 2-dimensional concept (Gonyou et al., 2006). A k value of 0.336 was the minimum space allowance for grow-finishing pigs on fully slatted floors.

Space needs for pigs in outdoor lots should be based on performance standards, not on hard-and-fast numbers. In cold weather, less space in outdoor lots is acceptable. Less space is needed in hot and dry weather than when the weather is hot and wet. Many factors must be taken into consideration when selecting the type of housing for finishing pigs.

Several alternative non-environmentally controlled finishing systems are acceptable for housing growing-finishing pigs. The most common alternative system is the bedded, naturally ventilated, open-air hoop building; these buildings are often bedded. Another alternative is indoor-outdoor lots. The floors in these types of facilities may be earthen or concrete. If the floor is concrete, it should be sloped to the outside. Bedding is often used in the sheltered areas of these open-front buildings but not in the run areas.

### **Breeding and Gestation Systems**

Sows, if managed properly, may be housed individually or in groups (McGlone et al., 2004b; AVMA, 2005). Both field and controlled studies (McGlone et al., 1994; PIC USA Inc., 1994; McGlone, 1995; McGlone et al.,

2004b; AVMA, 2005) support the idea that the individual crate or stall promotes high reproductive success and does not induce a distress response, based on endocrine and immune data. A properly designed individual stall or group system is an acceptable production system for teaching and research units. Newer systems, presently under development, require extensive evaluation before being introduced as standard housing systems. All housing systems have advantages and disadvantages associated with them (McGlone et al., 2004b; AVMA, 2005). Several gestation housing systems may be reasonable choices, including individual crates and variations of group pens (outdoor, individual feeders, electronic feeders, floor feeding, or trickle feeding). The tether system is not widely used throughout the United States and has been banned in the European Community member countries as of 1997; it is not a recommended housing system for gestating sows. Some individual states in the United States have banned or will phase out the use of gestation crates for sows. Teaching and research activities in states where gestation crates have been banned must comply with state regulations.

According to AVMA policy (2005), all sow housing systems should attempt to minimize sow aggression and competition especially at mixing and during feeding; provide sow protection from environmental extremes and hazards; provide feed and water; and allow sows to express normal behaviors. Moreover, if sows are to be housed in small groups they should be managed as a static group, whereas if they are to be housed in large groups they may be managed as a dynamic group. If possible, sows should be moved to new pens when new animals are introduced or mixed into the group. If no individual feeding system is provided and if possible, animals should be sorted and grouped based on established eating behavior. Sows in group pens (e.g., 5 to 10 per pen) and on restricted feed rations should be of uniform size and temperament. In extensive production systems, larger group sizes can be managed because feeding space per sow can be increased to reduce competition for feed.

#### **Building Environment for Breeding and Gestation.**

Suggested optimum range of air temperatures for gestating gilts and sows is 15 to 20°C (60 to 68°F). Nevertheless, it is important to remember that the effective temperature experienced by the gestating animal is a function of air temperature, relative humidity, air speed, wall and ceiling temperature, floor characteristics, body weight, feed intake, huddling, and number of animals housed together. Pregnant sows will start to experience heat stress when the air temperature is greater than 29°C (84°F). The lower critical temperature of a normally fed pregnant sow is between 20 and 23°C (68 and 73°F) for individually crated animals and approximately 14°C (57°F) for group-kept sows. The animal's behavior should be observed as an indicator of thermal comfort.

**Individual Stall Management.** Variation in physical size of sows exists not only within groups of sows at one location, but also occurs among farms (McGlone et al., 2004a). Data from a large sample of sows indicates that the size of the traditional gestation crate would have to be increased to accommodate the average sow (McGlone et al., 2004a) and it has been shown that a small increase in stall dimensions can reduce injuries and improve well-being of sows considerably (Anil et al., 2002). Sows should be in a pen or stall that allows them to lay down without parts of their body (not including their limbs) extending into the neighboring stall. Standing sows and gilts should not be forcibly in contact with the sides, ends, or top of the stall (Curtis et al., 1989), and sows housed in individual stalls should be able to lay down in full recumbency without their heads lying upon a raised feeding trough. This performance standard is consistent with standards of the National Pork Board (2002).

**Group Housing Management.** In the case of group housing systems, much of the aggression and competition associated with group housing can be influenced by feeding method, social status, and floor space per animal, group size, genetics, and management procedures. Thus, some of the many factors that should be considered when designing and implementing group-keeping systems are group size, floor space allowance, group composition (static vs. dynamic), diet type and method of feed delivery, genetics, and sow temperament (Levis, 2007). Group housing for sows may be indoors or outdoors, drylot or pasture, and insulated, mechanically ventilated frame structure, or hoop structure. Floor types may be solid or slatted, with or without bedding. Most importantly, group-keeping systems differ in terms of feeding, group management, and floor type. Some of the feeding systems include electronic sow feeders, drop or trickle feeding, and individual feeding stalls.

Social interactions are facilitated when sows are kept in groups, thus groups must be managed to reduce social stress. Aggressive behavior in swine is common, and serious injury can result if swine are left unattended. The social interaction among females in the pen is influenced by the number of females per pen, the area of space per female, variation in body size among females, duration of time together, and most importantly, method of feeding. When the group is fed a limited daily ration, competition for feed can be intense and, without intervention from animal care personnel or a physical system, aggressive sows overeat and subordinates ingest inadequate amounts of feed. Several feeding systems and management schemes can be used to minimize the aggressiveness of sows during feeding. Group housing systems include but are not limited to drop-feeding, trickle-feeding, and electronic sow feeding systems. An alternative is a group pen equipped with individual feeding stalls used only at feeding time.

In addition, there are 2 basic management schemes for group management—static or dynamic. When sows

are kept in small groups or groups up to 35 or 40 sows, they should be maintained as a static group (sows in same production phase), whereas groups of 80 to 200 sows may be maintained as a dynamic group (sows enter and leave the group every week). Minimizing social stress by keeping sows in individual stalls for the first 25 to 35 d post-breeding or grouping all sows at one time improves well-being.

Specific genetic strains of sows may differ in their ability to adapt to particular housing environments (Beilharz, 1982), but this hypothesis has not been fully investigated. Inputs from managers, proper habituation, and selection of appropriate genetic stock appear to be primary contributors to the well-being of sows, independent of the gestation systems used.

**Floor Space Allowance and Group Size.** Floor space allowance will vary with group size. Space for accessing necessary resources, opportunity to avoid or escape from potential aggressors, and avoidance of chronic physiological stress are essential for the well-being of low-ranking sows in group housing. Space should be adequate space to avoid physical injury. The minimum floor space allowance should be 1.49 m<sup>2</sup> per sow (16 ft<sup>2</sup>) on partly slatted floors (Salak-Johnson et al., 2007). For larger sows (based on body weight), floor space allowance should be 1.77 m<sup>2</sup> per sow (19 ft<sup>2</sup>); thus, as body weight increases, floor space allowance increases slightly. No optimal group size has been determined. Farrowing rate and litter size were not different when 10 sows per pen were housed at 1.95 m<sup>2</sup> per sow (13 ft<sup>2</sup>) compared with housing 5, 10, 20, or 40 sows per pen at 1.49 m<sup>2</sup> per sow (21 ft<sup>2</sup>) (Taylor et al., 1997).

**Mating Facilities.** Recommended areas for breeding sows and boars of different types and sizes are listed in Table 11-2. Sexual development of gilts that have been selected to enter the breeding herd is hastened when they are kept in groups (10 to 12 per pen recommended in intensive production systems) with the opportunity for contact with mature boars for at least 30 min/d. Individual housing of mature boars is recommended to preclude interactions among boars. When mature boars that are unfamiliar with one another are penned together, intense fighting usually occurs. In systems in which boars reside in small groups, boars should be of similar size, and it is highly desirable that they be reared together from the time of puberty. Stalls for boars should meet the same performance standards as for sows. However, larger stalls or pens may be required for extremely large boars.

Specialized facilities or areas are needed for breeding. Breeding may be by natural service or artificial insemination. Boar breeding areas should be slip-resistant. Artificial insemination areas include boar semen collection and sow insemination areas. Boar semen collection areas should be designed to consider boar and worker safety as well as animal comfort and sanitation. Sow insemination areas may be the same as gestation facilities for sows. The flooring surface in mating pens should be

considered during the planning and construction of the facility. In pens with an area of solid concrete, floors may be made slip-resistant by applying a wood float or broom finish or by placing grooves in the concrete. A 2.5-cm (1-in) diamond pattern has proved satisfactory (Levis et al., 1985). In pens used for hand mating but without good footing, absorbent substances or rubber mats may be placed on the floor.

Pen mating (placing a boar with sows unattended) and hand mating (personnel attending boar-sow matings) are mating options. With pen mating in pasture and drylot systems, primary considerations are to minimize extremes in environmental temperature, rest boars between mating sessions, and avoid putting young boars with old sows or old boars with gilts. For pen mating in intensive production systems, area allowance and flooring are additional considerations. Pens should meet the same performance standards for space and allow for ease of movements during breeding. One boar per pen is recommended. Slip-resistant, dry floors are required to prevent injury. With hand mating, the sow usually is mated in a designated mating pen but may be mated in the pen of either the sow or the boar.

Sows kept for several parities may require special attention. Animal caretakers should be aware of the possibility of shoulder sores, long hoof growth, and thin body condition. These and other health problems should be treated as soon as they are identified.

### **Metabolism Stalls**

Metabolism stalls are used to pen individual pigs for certain investigations of nutrition and physiology, with the approval of the IACUC. The metabolism stall usually (but not always) keeps pigs in a manner that precludes them from turning around and soiling feed or eating feces. If the flooring and penning materials are appropriate for the size of the pig to be used, and if the space allowances for individual pigs are met (Table 11-2), then pigs may be penned for extended periods in metabolism stalls without problems. The precise width of a metabolism stall may require adjustments to provide total urine and fecal collection while preventing the pigs from turning or flipping. Slightly smaller space allowances may therefore be needed to accomplish these objectives. In studies requiring the use of metabolism stalls, twice-daily interaction between the animal care staff and the pigs is especially important. Visual and vocal interactions with other pigs also support the well-being of individually housed pigs. Pigs should be held in metabolism stalls no longer than required by the approved animal care protocol.

## STANDARD AGRICULTURAL PRACTICES

### Castration

Boar taint, defined as a specific objectionable odor and flavor in meat, often occurs when boars are slaughtered at 100 kg (220 lb) of body weight or heavier. In view of the demand by US packers for heavier market hogs, almost all male pigs are castrated before slaughter. If teaching and research pigs are to be marketed in commercial chains, castration is recommended. If the research intends to reflect commercial pork production, castrated males are appropriate model animals. Castration causes clear signs of pain and discomfort for pigs (McGlone and Hellman, 1988; McGlone et al., 1993; White et al., 1995, Taylor and Weary, 2000; Hay et al., 2003; Prunier et al., 2005; Carroll et al., 2006). Signs of pain and discomfort may include reduced times spent nursing or feeding, increased vocalization (apart from that induced by handling) as pigs increase in age, inflammation and swelling at the castration site, acute reduction in performance, and hormonal responses. It is important to note that, while all authors reported some evidence of pain and discomfort, results were not consistent across experiments. To minimize stress on the pig, castration should be performed as early as possible and preferably between 1 and 14 d of age. After 14 d of age, local anesthetic or a combination of local and general anesthetic (Haga and Ranheim, 2005) should be administered before castration under prescription from the attending veterinarian. For boars of any age, trained personnel should use disinfected instruments, and a pre-castration disinfectant should be applied to the incision site. To allow proper drainage, the incision should be in the ventral scrotum and should not be sutured. Topical anesthetic may be used for short-term pain alleviation. Further information on castration can be found in Chapters 1 and 2 of this guide.

### Nose Rings

Outdoor swine production systems may have undesirable environmental consequences due to pig rooting behavior. Nose rings reduce rooting behavior (Horrell et al., 2001; Eriksen et al., 2006); however, pigs experience pain when fitted with nose rings and nose rings reduce rooting behavior by making it a painful experience. This presents an issue of environment versus welfare (McGlone, 2001). Nose rings have been shown to affect eating behavior (Horrell et al., 2000), and pigs will engage in other exploratory behaviors if they cannot root (Studnitz et al., 2003). Pigs should be fitted with nose rings only when the expected deleterious impact to the environment outweighs concerns regarding the welfare of the pig.

### Other Standard Practices

Several standard agricultural practices that cause only brief pain or distress but prevent more serious distress or injury later in the pig's life may also be performed. Thus, teeth of pigs may be clipped at a very young age to reduce damage to littermates and to the sow. No more than one half of the tooth should be trimmed. Ears may be notched to provide permanent individual identification. Tails may be docked to reduce the potential for tail-biting. Tusks of boars may be trimmed to prevent them from harming humans or other pigs. Sows and boars may have their hooves trimmed to allow them to walk with greater ease and to avoid injuries.

## ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of swine environments.

## HANDLING AND TRANSPORT

Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of swine.

## SPECIAL CONSIDERATIONS

### *Housing of Swine on Biomedical Protocols in Agricultural Facilities*

The *Guide for the Care and Use of Laboratory Animals* (NRC, 1996), also known as the ILAR Guide, states "Uses of farm animals in research, teaching, and testing are often separated into biomedical uses and agricultural uses because of government regulations (AWRs), institutional policies, administrative structure, funding sources, or user goals. That separation has led to a dual system with different criteria for evaluating protocols and standards of housing and care for animals of the same species on the basis of perceived biomedical or agricultural research objectives (Stricklin and Mench, 1994)." The ILAR Guide goes on to state "use of farm animals in research should be subject to the same ethical considerations as the use of other animals in research, regardless of an investigator's research objectives or funding source (Stricklin et al., 1990)." The ILAR Guide refers to this document (*Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching*, known as the Ag Guide) for farm animals in a farm setting. The USDA-APHIS also accepts the Ag Guide in their policy 29 ([http://www.aphis.usda.gov/animal\\_welfare/downloads/policy/policy29.pdf](http://www.aphis.usda.gov/animal_welfare/downloads/policy/policy29.pdf)).

Farm animals used for the purpose of agricultural research and teaching are covered by the Ag Guide. For the researcher, having 2 sets of standards for swine seems to be overly burdensome. It is therefore, rea-

sonable to consolidate these 2 sets of guidelines into a single workable set of guidelines for both the researcher and the IACUC. This idea has been suggested by others (Curtis, 1994) and, to some extent, by regulators such as USDA-APHIS.

For pigs used in biomedical research, their needs for thermal comfort, humidity control, floor space, and husbandry practices should be based on the performance standards outlined in this chapter. Pigs in certain biomedical settings and with certain genetic backgrounds may have special requirements that should be understood so that pigs are comfortable. The same performance standards that indicate adequate animal welfare for pigs in an agricultural setting will apply for pigs in a biomedical setting.

### **Pigs with Small Mature Body Size**

Some specific species of *Sus scrofa* or *Sus vittatus* have, naturally or through selection, a small mature body size. These include but are not limited to mini, micro, and potbellied pigs. These pigs may be used in commercial agricultural production, but are more often kept as pets or used as biomedical research models. However, the husbandry requirements of these pigs are generally similar to those of traditional domestic pigs, with some exceptions.

Thermal and nutrient requirements should be carefully considered. Pigs with small mature body size are more sensitive to cool temperatures than are larger pigs because of their sparse hair coat and small body size. Because they are smaller and eat less per day, their nutrient requirements per weight of feed may be higher, although they must be limit-fed to control body condition (avert obesity). The physical environment (e.g., flooring and penning materials) should be appropriate for their body size.

### **Genetically Engineered and Cloned Pigs**

A transgenic animal is one that carries a foreign gene that has been deliberately inserted into its genome. The foreign gene is constructed using recombinant DNA methodology. A cloned animal is made by a process in which an entire organism is reproduced from a single cell taken from the parent organism and in a genetically identical manner. Essentially, cloning involves removing the nucleus of a cell from an adult animal that will be copied and inserted into an animal egg whose nucleus has been removed. This technically means that the cloned animal is an exact duplicate in every way of its parents; it has the exact DNA. Cloning happens in nature when twins develop from a single fertilized egg. There are three major types of cloning technologies: recombinant DNA technology, reproductive cloning, and therapeutic cloning. The first successful genetically modified animal was a mouse (Gordon et al., 1980) and several years later, other transgenic animals were produced, including pigs (Pursel et al., 1987). The first

successful animal cloning was that of Dolly the sheep, who not only lived but went on to reproduce naturally (Wilmut et al., 1997).

Transgenic animals provide tools for exploring biological questions related to agriculture, medicine and industry. More specifically, using transgenic animals enables scientists to understand the role of genes in specific diseases, thus the use of transgenic animals yields a number of highly significant benefits. Despite the importance of transgenic animals in biomedical research, some concerns and misconceptions have been raised about their use in research. Transgenic animals may develop more abnormalities than non-genetically modified research animals because introduction of DNA into an animal can be very complex and possible side effects can be difficult to predict. Transgenic pigs with high levels of bovine growth hormone turn out to have no compromised welfare in the first two generations, but in the third generation infertility, nephritis, cardiomegaly, and arthritis were all reported (Pursel et al., 1989, 1993). Nevertheless, changes and improvements in growth hormone constructs have eliminated these problems in pigs (Nottle et al., 1999). However, it must be noted that some of these abnormalities are species-specific: cloned piglets (Carter et al., 2002) appear to have normal birth weights, whereas cloned calves and lambs have large birth weights (Wilson et al., 1995; Walker et al., 1996). There is some suggestion that immune function may be compromised in cattle (Renard et al., 1999), but cloned pigs appear to respond to vaccination (Carter et al., 2002). Although some groups have reported abnormal phenotypes in swine, others have seen few problems. In fact, transgenic pigs expressing human complement regulatory protein CD59 were all found to be healthy because there were no specific pathomorphologic phenotypes associated with the presence of the transgene in all pigs evaluated (Deppenmeier et al., 2006). Therefore, where transgenic animals are concerned, it remains important to expect the unexpected. Extra vigilance is required by researchers, animal technicians, and IACUC staff to ensure potential causes of pain and distress to experimental animals are quickly detected and treated or eliminated.

In January 2008, the FDA concluded that meat and milk from cow, pig, and goat clones and offspring of any animal clones are as safe as the food we eat every day. Despite the FDA response, it is still extremely important to track transgenic animals. The following methods are suggestions that have been shown to be successful for tracking: genetic and permanent identification processes should be used. From a genetic standpoint, a readily assayable sequence should be used for screening purposes. Also, transgenic pigs should be permanently identified in conjunction with specific color-coded ear tags. This permanent identification system should be unique and different from the conventional identification system commonly used in pigs. For example, a hole in the middle of each ear is not typical of the conventional system. Each animal within the herd should have

a unique number and numbers should never be reused. Each individual pig must be traceable to a particular founder sire and dam. The place, date, and time of birth; use of the pig in production; incidence of disease; and final disposition should be recorded for each pig. Animals that have incorporated the transgene DNA but are not producing the transgene product should be distinguished from animals that have not incorporated any exogenous DNA (FDA, 1995). If an animal's genotype is in question, then it should be considered transgenic and disposed of following the proper guidelines. If cross-fostering is used, animals should be cross-fostered only within the transgenic herd. The genetic background and history of the animals that will provide gametes (donors) and of the foster or recipient animals should be known in detail and should include the species, breed, country of origin, general health, and other available genetic and pedigree information. The pigs to be used should have detailed health evaluations, including specific tests for species- and breed-related disease problems. For the control of disease agents, the donor and recipient animals should meet the same criteria used for all other outside animals entering the herd (FDA, 1995; <http://iets.org/pdf/HASAC-HealthAssessmentCare.pdf>).

Detailed plans for maintaining transgenic animals should be developed. Plans for periodic monitoring of pig health and housing facilities for transgenic animals as well as plans for removal from production and disposal of the animals or their byproducts should be carefully described in the experimental protocol and approved by the IACUC, in accordance with the Animal Welfare Act (7 U.S.C., Sec. 2131 et seq.) and, the Public Health Service Act (42 U.S.C., Sec. 289(d)) where applicable (FDA, 1995). For cloned pigs, the International Embryo Transfer Society (IETS) has developed guidelines titled "Health Assessment and Care for Animals Involved in the Cloning Process" (IETS, 2008; <http://iets.org/pdf/HASAC-HealthAssessmentCare.pdf>). "The containment and confinement practices for production operations involving transgenic animals should be in accordance with applicable portions of the NIH guidelines for Research Involving Recombinant DNA Molecules. The physical surroundings where the transgenic animals will be maintained should be described in detail, see requirements at 21 CFR 600.11. Information should include herd size, physical isolation and containment, breeding isolation, and biosafety-containment (when appropriate). If the facility is not a single-species-dedicated breeding and maintenance facility, the adventitious agents of the other species must be considered. The surroundings should be capable of containing the animals and of preventing the accidental entry of other animals. Transgenic animals should be neutered after breeding to lessen the chance of escape or inadvertent breeding into the nontransgenic population(s)" (FDA, 1995).

The founder animals should be evaluated to determine whether the transgene is being expressed in a site-

specific manner if that is the intent of the transgene introduction. The high levels of tissue-specific protein expression of certain transgenes may cause adverse side effects or may affect expression levels of endogenous proteins, (i.e., by interfering with or modifying their function) leading to adverse consequences that compromise the health and usefulness of the animals (FDA, 1995). Finally the disposition of pigs to be used as food is regulated by both the FDA (CVM or CFSAN) and the USDA Food Safety and Inspection Service (FSIS) when they are of an inspected species being offered for human food (FDA, 1995). In general, disposal of transgenic animals, including retired or dead animals, should be in accordance with the applicable portion of the NIH guidelines for Research Involving Recombinant DNA Molecules; contact the FDA CVM for guidance.

## EUTHANASIA

The National Pork Board in collaboration with the American Association of Swine Veterinarians developed guidelines titled "*On-Farm Euthanasia of Swine—Recommendations for the Producer.*" This document, which may be viewed online (<http://www.aasv.org/aasv/documents/SwineEuthanasia.pdf>) describes 6 accepted methods of euthanasia and clearly notes which methods are most appropriate for pigs from newborns to adults. Human safety risks associated with administering each method of euthanasia are addressed. Blunt trauma is acceptable for pigs weighing less than 5.5 kg. Carbon dioxide is a suitable method for euthanating pigs less than 10 wk of age providing that residual oxygen is removed quickly from the CO<sub>2</sub> chamber. Carbon monoxide is not recommended because it is a potential human health hazard. An overdose of anesthetic, injection with a euthanasia solution, and electrocution are suitable for pigs of all ages and are humane methods that may be practiced after careful training. Barbiturates require special handling and licensing. Gunshot and captive bolt with exsanguination are appropriate for pigs weighing more than 5.5 kg. Other recommended methods may be used if proper equipment and expertise are available.

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