Review of housing options for gestating sows

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Abstract
Housing options for gestating sows is an important topic affecting livestock producers, consumers, and policy makers. Producers seek to provide high quality products at affordable prices while meeting increasing public demands for animal wellbeing. Several studies have been conducted over the years to compare group and individual housing options for gestating sows. The object of this paper was to review these studies and to look specifically at the areas of animal wellbeing and economic impact of housing type. Several types of housing and feed management plans were examined from previous studies and the impact of housing type was explored. Overall, studies show that group housing can maintain animal wellbeing while still remaining economically feasible. Legislation has already been passed by the European Union to ban individual stalls starting in 2013. The future of gestation housing in the US pork industry is uncertain, but it appears that changes are coming quickly.

Keywords
Gestation, housing, swine, welfare, economics

Disciplines
Agriculture | Bioresource and Agricultural Engineering

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Abstract. Housing options for gestating sows is an important topic affecting livestock producers, consumers, and policy makers. Producers seek to provide high quality products at affordable prices while meeting increasing public demands for animal wellbeing. Several studies have been conducted over the years to compare group and individual housing options for gestating sows. The object of this paper was to review these studies and to look specifically at the areas of animal wellbeing and economic impact of housing type. Several types of housing and feed management plans were examined from previous studies and the impact of housing type was explored. Overall, studies show that group housing can maintain animal wellbeing while still remaining economically feasible. Legislation has already been passed by the European Union to ban individual stalls starting in 2013. The future of gestation housing in the US pork industry is uncertain, but it appears that changes are coming quickly.

Keywords. Gestation, housing, swine, welfare, economics
**Introduction**

In recent years, the swine production industry has received increased pressure to move away from individual gestation housing units towards group housing systems. An increased concern for sow welfare has led many to question the practices used for sow production. A group housing system is believed to reduce stress, increase social interaction, and promote the general wellbeing of the animals. Some research has been conducted to compare these two methods, and to see if differences exist. Several factors have been examined, including group size, space requirements, feeding options, and the economic differences between the two types of systems. The difficulty in comparing the two systems is quantifying animal welfare. Studies have used several methods, including weight gain, chemical concentrations within the bloodstream, and oral-nasal-facial behaviors (ONF).

The European Union has already passed legislation to ban individual gestation stalls beginning in 2013. Groups in the United States have also begun to press for legislation, and the future of the industry appears to be uncertain. If changes do occur, a complete understanding of optimal group housing systems is required. Housing units will have to be able to adapt in order to maximize efficiency and revenue, as well as promote animal wellbeing.

Within the U.S. swine industry there has been a growing trend to move away from individual housing to group housing for sows during gestation. This change can be attributed to outside political and public influences. The industry has evolved much over the past 50 years and moved towards more streamlined processes and greater production efficiencies. Early swine production conditions were typically smaller and allowed for open roaming. This practice shifted to smaller pastures, and eventually to the present day confinement practice. However,
this move toward more efficient, controlled environments has raised questions about animal wellbeing. Housing sows within individual stalls restricts movements, social interactions, and can increase stress and anxiety.

Several European countries have banned the use of gestation stalls, and by 2013 the use of such stalls will be limited to the first four weeks of gestation (Harris et al. 2005). Within the United States there is increased pressure to follow the EU and limit the use of gestation stalls. It is estimated that two-thirds of the sows in the United States spend the gestation period in stalls (Barnett et al. 2001). Public awareness about animal wellbeing has increased, especially in the last decade, and states such as Arizona, California and Florida have since banned the use of gestation crates (Tonsor, et al., 2009). Several large restaurant companies have also banned or plan to eliminate the use of pork produced from gestation crates including Arby’s, Subway, Applebee’s, and McDonalds (The Humane Society of the United States 2013). The United States has typically had less expensive food prices than other parts of the world, due to high efficiencies, and implementing such policy may potentially lead to increased meat prices. However, consumer willingness to pay higher prices to improve animal wellbeing can be positive (Carlsson, et al., 2007). It appears that the swine industry will be forced to adapt, due either to legislative measures or public desire, to produce meat from sources other than confined operations, especially gestation stalls.

Over the past several decades, the U.S. swine industry has moved away from smaller, independent producers to larger, consolidated operations. The industrialization of agriculture during the 1900’s impacted every aspect of crop and livestock production. Efficiency and economies of scale became driving factors for the consolidation of hog production. Figure 1
shows the number of hog farms compared to total production in the United States. Pork production increased from the mid-1970s through the 1990’s while the number of producers dropped drastically.

Figure 1: Pork production in the United States (Barkema and Cook 1993).

The movement has been towards a vertical integration structures where larger corporations control most, if not all, of the operations within the supply chain. During the late 1990’s, hog prices reached record lows, further forcing many smaller operations to shut down. Food prices within the United States have been able to stay low due, in part, to the consolidation of these operations. However, public concern over the conditions of hogs in these types of housing units has increased.

The objective of this paper is to review key issues related to gestation housing. Topics will include social and political factors, group housing: space allowances, economics, types of
group housing, types of feed delivery, impacts of group size, impacts of feeding area and impacts of diet and eating habits.

Social and Political Factors
Perhaps the greatest motivation for the change in sow housing is due to the change in societal views on animal welfare. The cost of food in the United States has typically been lower than most of the rest of the world. Production economics involve a myriad of factors, but one reason is that of efficiency: what is the fastest, least expensive way to get the food from producer to the consumer? However, there has recently been a paradigm shift that looks beyond the simple economics, and at factors that are harder to quantify in terms of cost. Public perceptions and ethical implications are becoming significant factors, and consumers are making their opinions heard. Many suppliers are feeling pressure to serve food that has been ‘ethically raised.’ A recent survey of US consumers showed that the public support on a ban for gestation housing was mixed (Tonsor, et al., 2009). Support for a ban was at 69% until consumers were told that the price of pork alone could see an increase of nearly $2/lb. Support then fell to nearly 30%.

As a society, the desires for food are similar those for fuel: cheap, reliable, and ethical (although not necessarily in that order). However, it is very difficult to simultaneously achieve all of these desires, and some concessions must be made. According to Tonsor et al. (2009), it has been estimated that consumers would support up to a $230/year increase in total household food prices in order to support a gestation ban.

As a result of consumer feedback and pressure, several measures have been taken in order to change current practices for animal housing. The European Union has already
implemented a ban on gestation that will go into effect in 2013 (Tuyttens, et al., 2011). Within
the US, bans have already gone into effect in Florida and Arizona. Other states such as
California are expected to pass legislation soon.

**Group Housing: Space Allowances**

Studies have been conducted to compare different types of housing and to observe the
effects upon the hogs. Much of the debate within the industry has been over group versus
individual housing, specifically for sow gestation housing. Social interaction is an important
aspect of swine production and group housing allows more than individual housing does.
Observations have been made on wild sows which found that group size will depend largely
upon availability of resources. Primary groupings will consist of between two to four sows
along with their most recent litters (Gonyou and Keeling 2001). Within these groups, a social
hierarchy will be formed between dominant and subordinate sows. These interactions are
important for the physiological wellbeing of the hogs.

There has been an increase in the number of studies concerning group housing for sows.
One of the factors to consider is the minimum space requirement for a group. The wellbeing of
the animal can be quantified by any number of methods: fidgeting, food/water consumption,
chemical secretions in the blood, and physical ailments such as skin lesions. Most studies have
observed group housing where the space per pig ranges between 1 m²/pig and 4 m²/pig. Most
have reported there is little to no decrease in health and reproduction for group housing
compared to single stall housing. In one study, McGlone et al. (2004) observed the release of
corticotropin-releasing factor (CRF), which can increase heart rate and blood pressure.
Weng et al. (1998) compared four pen sizes (2.0, 2.4, 3.6, and 4.8 m²/pig) for groups of six pregnant sows. The study recorded interactions of the sows and noted changes in social interactions. Additionally, the study observed body lesions that formed due to excess inactivity. The study noted that time spent rooting increased as available space increased, and that the time spent sitting or standing inactive increased as available space decreased. The most important factor was that enough space be provided to prevent the development of skin lesions. The study found that space requirements of between 2.4 m²/pig and 3.6 m²/pig are required to maintain the wellbeing of the animals. Social interactions were found to be more favorable in pens greater than 2.0 m²/pig. Initial aggression was found to be lower for smaller pens, but over time aggression increased between social groups (Weng, et al., 1998).

**Economics**

The economics of individual and group housing was studied by Lammers et al (2008). The study looked at construction and operating costs for individual gestation stalls in a confinement building, and group pens with individual feeding stalls in hoop barns (Table 1). Hoop barns were analyzed due to their construction cost being 70% of that for typical confinement buildings. Their analysis was broken down on a cost per weaned pig comparison. The constructed hoop barns occupied an area of 2 ha and housed 1700 sows. For the construction costs, the hoop barn was found to be much lower than the confinement cost, most notably due to the differences in ventilation system costs. Hoop barns do not require ventilation as they are open and freely circulate air.
Table 1: Estimated construction cost per sow of two gestation systems (Lammers, et al., 2008).

<table>
<thead>
<tr>
<th>Item</th>
<th>Conf[b] ($)</th>
<th>Hoop[b] ($)</th>
<th>Hoop: Conf (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land costs[c]</td>
<td>4.41</td>
<td>17.65</td>
<td>400.0</td>
</tr>
<tr>
<td>Building structure[d]</td>
<td>265.00</td>
<td>249.94</td>
<td>94.3</td>
</tr>
<tr>
<td>Ventilation system[d]</td>
<td>150.00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Flooring and manure storage[d]</td>
<td>135.61</td>
<td>78.13</td>
<td>57.6</td>
</tr>
<tr>
<td>Feed and water system[d]</td>
<td>71.20</td>
<td>58.77</td>
<td>82.5</td>
</tr>
<tr>
<td>Other expenses[d]</td>
<td>193.78</td>
<td>165.51</td>
<td>85.4</td>
</tr>
<tr>
<td>Total construction cost</td>
<td>$820.00</td>
<td>$570.00</td>
<td>69.5</td>
</tr>
</tbody>
</table>

[a] Assumes facilities to house 1,700 sows.
[b] Conf = individual gestation stalls in confinement facility; Hoop = group pens in hoop barns with individual feed stalls.
[c] Calculated: Conf = (0.5 ha x $15,000/ha) + 1,700 sow spaces; Hoop = (2.0 ha x $15,000/ha) - 1,700 sow spaces.

Error! Reference source not found. shows the total operating and fixed costs for the two housing units. It has been noted that housing conditions may affect litter size and these discrepancies have taken into account. Their final analysis showed that a hoop facility has an overall 10% lower cost per weaned pig than a confinement facility. The set up for this hoop facility also has individual feed stalls, which allows for control over feeding rates (Lammers, et al., 2008).
Table 2: Estimated total cost per sow of two gestation systems (Lammers, et al., 2008).

| Item                                | Conf[b][c] | Hoop[b][d] | Hoop:Conf (%)
|-------------------------------------|------------|------------|----------------
| Pigs                                | 9.1        | 9.8        | 108            |
| **Operating Costs**                 |            |            |                |
| Feed                                | $6.83      | $6.79      | 99             |
| Labor                               | $6.96      | $6.46      | 93             |
| Breeding/genetics charge            | $5.15      | $4.78      | 93             |
| Bedding                             | $0.00      | $0.84      | na             |
| Utilities, fuel, and oil            | $1.80      | $0.67      | 37             |
| Transportation, marketing           | $1.76      | $1.63      | 93             |
| Veterinary, drugs, supplies         | $1.00      | $0.93      | 93             |
| Professional fees                   | $0.48      | $0.45      | 94             |
| Operating costs subtotal            | $23.98     | $22.56     | 94             |
| Interest on 1/2 operating costs     | $0.84      | $0.79      | 94             |
| Total operating costs               | $24.82     | $23.35     | 94             |
| **Fixed Costs**                     |            |            |                |
| Depreciation                        | $3.29      | $2.57      | 78             |
| Interest                            | $3.11      | $2.43      | 78             |
| Insurance and taxes                 | $0.94      | $0.74      | 78             |
| Repairs                             | $1.82      | $1.42      | 78             |
| Total fixed costs                   | $9.16      | $7.15      | 78             |
| **Total costs per litter**          | $309.22    | $298.83    | 96.6           |
| Total costs per weaned pig          | $33.98     | $30.49     | 89.7           |

[b] Conf = system that uses individual gestation stalls;
Hoop = system that uses groups pens in deep bedded hoop barn with individual feeding stalls for gestation.
[c] Costs from table 2 divided by 9.1 pigs.
[d] Costs from table 2 divided by 9.8 pigs.

Other studies show that the initial cost of constructing a hoop barn for group housing may be higher, depending on the specific layout. Factors contributing to the potential higher cost include installation of an elevated platform and feeding stalls (Harmon, et al. 2007). Feeding stalls would increase cost but could be used for vaccinations, artificial insemination, and inspection of individual animals.
Hoop barns are a relatively recent type of housing but are certainly not the only type available to producers. Alternative types of group housing are available that, depending on available resources can prove to be quiet economical. In a European Commission report, the general estimate was found that for every increase of 5.4 ft\(^2\) (0.5 m\(^2\)) space per sow, the capital cost rose 1% (Scientific Veterinary Committee 1997). A report by the Human Society of the United States (2011) did a cost comparison for individual and group housing. In general, the total cost for group housing was found to be higher than individual stall housing (The Human Society of the United States 2011).

**Types of Group Housing**

If the future of gestation housing is moving towards group systems, the next question to address is how large a group is most effective? Many studies have been conducted to investigate the minimum space required per sow in a group setting, but many factors change as group size changes. Animal interactions are an important part of the health and wellbeing of sows, and because social hierarchies are established between groups, adequate spacing is required. Dominant sows emerge within groups and subordinate sows require space to avoid conflict.

In a study by Taylor et al. (1997), it was found that group size had no effect on reproductive performance. In the study, sows were housed in groups of 5, 10, 20, and 40, each with a space allowance of 2 m\(^2\)/sow, and they found no differences. However, when space allowance was reduced from 2 m\(^2\)/sow to 1.2 m\(^2\)/sow, animal aggression increased. Olsson et al. (1994) reported that as group size increased, the risk of injury increased. On the other hand, Weng et al. (1998) reported that decreases in group size could result in higher levels of animal
aggression. They suggested that for groups of 6 sows, space allowances should be between 2.4 and 3.6 m²/sow.

Group housing has traditionally been indoors, but outdoor housing is also possible. In fact, New Zealand and the UK have 20-30% of sows living outdoors (Barnett, et al. 2001). Outdoor housing is more difficult due to the change in temperatures throughout the seasons and the possibility of adverse weather. Outdoor housing presents additional challenges, such as predator control, increased foraging, and feed management. Outdoor housing can be a possibility, but is more difficult to regulate and provide water.

**Types of Feed Delivery**

One of the key issues with group housing is ensuring that adequate feed is available for all animals. Limited availability of feeding space/stalls makes equal feeding to all animals in a group more challenging. Offering a constant supply of feed would allow sows to eat to satiation and minimize the competition for available resources. However, without a limit on available feed, the potential for overeating exists. Sows also are found to consume more food and water when a constant supply is present. One study showed that sows continually play with nipple drinkers and consumer 2-3 times more water than normal (Fraser and Broom 1997).

There have been several methods investigated for improving feeding of sows in group housing. For example, with daily feeding, sows can learn to follow scheduled times for eating and are allowed only a limited amount of time. Feeding can be done by group self-feeders or by feeding stalls in which feed one sow at a time. Interval feeding allows the sows to eat every two or three days in groups until satiated, but then aren’t allowed to eat again until after two or three days. Individual feeding allows greater control over intake but can me more expensive.
to implement. Electronic feeders may be used for larger groups of sows (50+ sows per feeder) and can be automated. However, these feeders require a large capital investment and can be problematic if prolonged periods of power outage occur.

**Impacts of Group Size**

The size of groups in sow housing is a very important issue to consider. Currently, indoor housing of sows with 2 – 20 sows within a single group is fairly common. With space requirements of adult swine in the range of 1.4 – 1.8 $m^2$/pig, a study was done to compare the health and welfare of sows. The number of sows in each group tested was 5, 10, 20 and 40, with a space allowance of 2 $m^2$/sow, which was larger than what was required. Overall, there was no impact on the reproductive performance between the groups. Similar numbers of piglets born per sow and stillbirths were recorded between each group size. Although an increase in aggression was observed as the size of each group increased, this did not lead to an additional number of lesions across the groups. Each group had a similar number of lesions. The space allowance was then decreased from 2 $m^2$/sow to 1.2 $m^2$/sow. Again, increased aggression was observed for all groups, but this did not lead to a significant increase in number of lesions between the groups (Barnett, et al. 2001).

Some experimental housing units have been established in parts of Australia, Canada, and the United States that house much larger groups of sows. They consist of hoop buildings that can house up to several hundred sows. In one area, bedding is used to absorb feces and urine which provides elements more similar to their natural environment. Even some sticks or other debris is provided for rooting and chewing if desired (Barnett, et al. 2001). Although the group sizes may be bigger, this more natural environment might not increase aggression to the
level usually seen in larger groups as long as simultaneous feeding is done (Scientific Veterinary Committee 1997).

Stable hierarchies have been observed in groups of 8-20. One experiment tested the density of the pigs in a few different group sizes to see the interactions of group size and group density, and then how those variable changes impacted the health of the pigs. Three group sizes were tested (10, 20 and 40) with a common density for all of the groups of 0.8 m²/pig which is below recommended industry practice. Only in the group of 40 pigs per pen was there an increase in injuries and death, which was most likely a result of heightened aggression due to the greater number of pigs and the decreased density (Scientific Veterinary Committee 1997).

As mentioned previously, aggression is more frequently observed in larger groups and also when unfamiliar sows are mixed together (Rhodes 2005). In general, increased aggression most often leads to lesions due to fighting until a stable hierarchy is determined (Scientific Veterinary Committee 1997). Especially during pre-partum, or birth, sows seek seclusion for nesting in the wild. In industry, this is seen as an increase in motility, but is really the sow’s natural instinct to protect her young and herself from other sows until about a week or two after birth, regardless of the group size (Barnett, et al. 2001).

Aggression aside, group size (or the housing type that can impact group size) does not appear to be significant a factor in overall health. Daily management, pathogen exposure, geographical location, biosecurity measures, and other factors are deemed higher factors of importance (Rhodes 2005). Once a pig is sick or is suspected of showing symptoms, management is key in order to isolate that particular pig to keep the health issue from
spreading and to administer appropriate care (Mitch McDermott, swine producer, personal communication, 10 October, 2012).

The social aspects of group size vary. For the producers, it is more economical to house pigs in larger groups (Rhodes 2005) but is better, health-wise, to house sows in individual, or stall, housing (Scientific Veterinary Committee 1997). Individual housing can lead to more attention to each individual sow, but can decrease the overall welfare of the sow due to limited social interactions with other sows. This can pose an issue, since tether and individual stalls are viewed to have lower welfare ratings for sows, and group housing has had the best welfare ratings (Rhodes 2005). In the eyes of the public, this can cause uncertainty and misunderstandings. This may cause the introduction of new codes, regulations, or the adjustment of existing ones as a result of public emotion rather than actual fact based research (Barnett, et al. 2001). As an example to show the economic impacts of switching housing structures in order to accommodate group sizes, Table 3 shows the costs of switching from individual housing to group housing for dry sows in Europe (Scientific Veterinary Committee 1997).

<table>
<thead>
<tr>
<th></th>
<th>Investment building/sow</th>
<th>Housing cost/sow/year</th>
<th>Total cost/sold piglet</th>
<th>Labour income</th>
<th>% change in labour income</th>
<th>Change of cost price per kg fattening pig</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Individual</strong></td>
<td>2617</td>
<td>353.56</td>
<td>56.71</td>
<td>14863</td>
<td>100%</td>
<td>1.580</td>
</tr>
<tr>
<td><strong>Group housing</strong></td>
<td>2564</td>
<td>346</td>
<td>56.37</td>
<td>16062</td>
<td>+8%</td>
<td>-0.004</td>
</tr>
</tbody>
</table>

* basic situation
Impacts of Feeding Area

The areas in which animals are fed play a very important role in the health and welfare of any animal, and sows are no exception. There is a variety of feeding area types: individual feeders, group feeders, putting feed in a pan, putting feed on the ground, in an enclosed pen, etc. Figure 2 illustrates an example of stall housing, which entails an individual stall per sow and which has an area for feed and water. In this particular example, there is a portion of the floor that is slotted (in order for feces and urine to fall through) and a solid portion where the sow will lay down. This laying area is also next to the food and water, because pigs do not eat and sleep in the same area where they defecate (Scientific Veterinary Committee 1997).

![Stall Housing Diagram](image)

**Figure 2: Stall housing for pregnant sows** (Scientific Veterinary Committee 1997).

The housing and feeding arrangement in Figure 2 ensures that the sow will be alone while eating and will not have to fight or jostle for position with other sows in order to eat. Eliminating the interaction with other sows helps ensure the sow’s protection from biting or bunting from other sows. Although Figure 2 has a trough for feeding, stalls are not required to have a trough, as some producers may elect to simply dump the feed on the ground or feed the sow by another means. The cheapest method would be to throw the feed on the ground and
let the sows eat in that manner (Scientific Veterinary Committee 1997), however, more feed will be lost due to the lack of containment, because the pig can push or spread out the feed (Mitch McDermott, swine producer, personal communication, 10 October, 2012). Individual feeders provide a containment method for the feed, but this generally increases capital costs by 74% compared to dumping the feed on the ground. An example of an individual feeder system is shown in Figure 3. Although this depicts a group housing arrangement, the aspects of an individual feeder remain the same: the sow is allowed individualized access to feed without competition, and is normally closed to the communal laying area except during feeding (Scientific Veterinary Committee 1997). In Figure 3, individual stalls isolate the sows while they are eating separately from the laying area, but the sows may still bite or jostle for position for a stall. Which stalls are highly sought after may depend on factors such as from which end of the feeding passage does the feed reach first, or where there might be a consistently large pile of feed due to initial pouring or mechanical issues with the auger (Mitch McDermott, swine producer, personal communication, 10 October, 2012).
Figure 3: Group housing for pregnant sows with individual feeding stalls (Scientific Veterinary Committee 1997).

A cheaper method of feeding compared to individual feeding stalls is cubicle housing and feeding, which can be seen in Figure 4. In this arrangement, the feeding and laying area are combined and not completely isolated, as in the individual feeding stall system. This can reduce capital costs by 23-26% because shorter stall walls do not encompass the entire sow, and therefore do not require a back gate. A back gate would prevent faster-eating sows from eating their share and then quickly pushing slower eating sows out of the way in order to gain access to more feed. It has been noted then that in a situation like this, it would be wise to match sows that eat at similar rates so no one sow gets done before another (Scientific Veterinary Committee 1997).
Figure 4: Cubicle housing for pregnant sows (Scientific Veterinary Committee 1997).

The mechanisms by which feed is delivered must be matched with the type of feeding area that is being used. This is critical in terms of timing. For example, if individual stalls are used for feeding the sows, feeding the sows by hand would be sufficient. However, if the feed is dumped in an open area or cubicle housing is used, it is important for the feed to be delivered simultaneously to each sow to minimize competition. An auger or other conveying mechanism can be used to accomplish this. This greatly helps to reduce the amount of fighting over which sow gets to eat first since feed is available in each area (Scientific Veterinary Committee 1997).

Another example is a 2-stage feeding area, in which unfed sows are all grouped together on one side. Then the unfed sows walk through an open gate into an individual pen that would trigger feed and water to be dispensed and the gate to shut. After the feed and water are consumed, the sow exits through a second gate into an area with already-fed sows, and the entrance gate opens again. While this would ensure sow isolation and the general same
temperament among each group, sows would most likely still be fighting to go through the entering gates first. At least until a hierarchy is established, aggression may be commonplace on the unfed side during feeding time (Scientific Veterinary Committee 1997).

**Impacts of Diet and Eating Habits**

Sows’ eating habits are not very particular since swine are omnivorous (they will eat both plants and animals). While plants and plant-based foods consist of the majority of a pig’s diet, it is not uncommon for earthworms and small vertebrates (for example, frogs and rodents) to be found inside the stomachs of feral pigs (Scientific Veterinary Committee 1997). However, it is in the best interest of the producer, and the sow, that a balanced diet is provided (Barnett et al., 2001). The diet chosen by a producer depends on several things, including age, pregnancy stage, but most importantly, ingredient price and availability.

Housing and feeding area play a large role. If the sows are fed outdoors or in a building with slotted floors, a diet that consists of large quantities of food would not be out of the question. Although large quantities of feed would also increase the amount of feces produced by each sow, the amount of feces being produced would be more cumbersome in an enclosed area that had a solid floor, thus requiring more frequent removal. Also, if the feed has a high concentration of protein, the producer would not want to feed a large quantity of this to the sows. Thus, less feed would be required in order to meet nutritional needs and may be easily distributed by hand (Rhodes 2005).

In order to calculate required nutrients, producers estimate the number of piglets and approximately what time of year the sow needs which type of feed. During 1991, 22.25 piglets per sow per year were produced in the top one-third of Canadian farms. In 1996, 30 piglets per
sow per year became a realistic commercial goal for producers. The increase in litter size also increased the amount of milk which needed to be produced. Sows need energy for maintenance, growth to maturity, pregnancy and lactation. This is complicated since the growth of a sow is not constant, and tissue losses from lactation need to be replaced during gestation (Patience 1996).

Maternal weight gain, according to Patience (1996), should be about 25 kg per parity (defined as having given birth) or 30 kg per parity, according to Barnett et al. (2001), up until the fifth parity. However, both agree that total weight gain per parity should be about 45 kg: 25 kg maternal weight gain and 20 kg of reproductive tissue. Following birth, the sow starts to lose weight, because the sow is producing nutritious milk for the piglets. Of those nutrients most needed, protein ranks nearly the highest, since it is necessary for piglet growth. Table 4 shows the amount of milk consumed and the corresponding estimated amount of weight gain by the piglet after birth (Patience 1996).

Table 4: Piglet growth curve and estimated milk output (Patience 1996).

<table>
<thead>
<tr>
<th>Days post-partum</th>
<th>Piglet weight gain (g d⁻¹)</th>
<th>Milk output (kg d⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–7</td>
<td>130</td>
<td>5.2</td>
</tr>
<tr>
<td>8–14</td>
<td>190</td>
<td>7.6</td>
</tr>
<tr>
<td>15–21</td>
<td>260</td>
<td>10.4</td>
</tr>
<tr>
<td>22–28</td>
<td>275</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Assumes 10 piglets per litter weighing an average 1.4 kg at birth and 7.4 kg at weaning, without benefit of creep intake. Derived from Whittemore and Morgan, 1990.

Generally, the daily amount of milk required to be produced by a sow is:

\[
\text{Milk Production} \left( \frac{g}{\text{day}} \right) = \text{Piglet Gain} \left( \frac{g}{\text{day}} \right) \times \text{Number of Piglets per Litter} \times 4
\]
This equation arises because the ratio of piglet weight gain to milk consumed is approximately 1:4. At 22-28 days post-partum (shown in Table 4), the 11 kg per day of milk production exceeds the physiological capacity of sows (not specifically chosen for lactation). Even with fat stores built up during gestation, which are used during lactation, much stress will be put upon the sow to produce enough milk for her young. Table 4 also assumes a litter of 10 piglets, which is well below the commercial goals of producers. Earlier weaning would be one solution to this problem, and would benefit both the sow and the piglets, but the piglets would still need a high energy feed, similar to sow's milk, in order to keep gaining weight appropriately (Patience 1996).

Overall, at least three things complicate the estimation of nutrient requirements of sows (Patience 1996):

1) The need to integrate the productive processes in both the sow (lactation or gestation) and the associated litter [piglet growth],

2) The potential contribution of sow body tissue stores to the productive process,

3) The interrelationship between events in the gestation and lactation periods

Table 5 further displays this complexity, and it shows nutrient requirements of gestating sows, protein in particular. Furthermore, what is appropriate for one sow may not be appropriate another, since they may gain or lose weight at different rates due to genetic differences.
Table 5: Dietary protein requirements (g per day) of gestating sows of differing maturity (Patience 1996).

<table>
<thead>
<tr>
<th>Parity</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body protein mass (kg)</td>
<td>16.6</td>
<td>27.7</td>
<td>35.5</td>
<td>40.1</td>
<td>42.5</td>
<td>45</td>
</tr>
<tr>
<td>Maintenance (g d(^{-1}))</td>
<td>88</td>
<td>119</td>
<td>148</td>
<td>164</td>
<td>173</td>
<td>182</td>
</tr>
<tr>
<td>Growth (g d(^{-1}))</td>
<td>97</td>
<td>68</td>
<td>40</td>
<td>21</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>Uterine/mammary (g d(^{-1}))</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Total—ideal</td>
<td>220</td>
<td>222</td>
<td>223</td>
<td>220</td>
<td>229</td>
<td>217</td>
</tr>
<tr>
<td>Total—dietary (^a)</td>
<td>293</td>
<td>296</td>
<td>297</td>
<td>293</td>
<td>305</td>
<td>289</td>
</tr>
</tbody>
</table>

\(^a\) Assuming 75% utilization of protein in a practical pig diet.

The nutrient content of the feed is crucial and, as previously shown, can be estimated by knowing the nutrient requirements of a sow, which depend on parity and age. However, like any animal, if a sow (especially a dry sow) consumes too much feed, they can become obese by eating in excess. This can affect the sow and its piglet negatively. If the producer lets the sows eat ad libitum (“at one’s pleasure”), then a bulky diet with a low nutrient density would be most appropriate (Scientific Veterinary Committee 1997). Likewise, if the sows are only allowed to eat during certain times of the day, or for a limited time, nutrient-dense feeds would be more desirable. In the wild, pigs walk and explore areas due to hunger in order to find food. This leads to constant movement and rooting until the hunger is satisfied (Rhodes 2005).

Also, choosing to have a low volume, energy-dense feed might leave the sows feeling constantly hungry for the majority of the day. Even though the feed has the required nutrients, the lack of volume can lead to welfare and aggression issues (Rhodes 2005). In some production facilities in North America (but not in Europe), some facilities practice “interval feeding”. Interval feeding is when sows are allowed full access to the feeding area where they can eat as much as they want/can, but only for a limited time. Some facilities may allow access to the feeding area 8 hours every second day, or 24 hours twice weekly. Again, this may cause
hunger, which can lead to poor sow welfare and spur public criticism for such a drastic feeding program (Scientific Veterinary Committee 1997).

Conclusions

Animal management is changing, and the status quo will no longer suffice. Between consumer concern, government regulation and pressure from large companies, it appears that the phasing out of individual gestation stalls for sows will be a matter of when, not if. The transition has already begun in Europe, and several states and companies within the US are beginning to follow suit. Surveys among American consumers show there is a willingness to pay more for pork that is raised in a group environment, but, there is a limit to how far consumers are willing to go. An increase of more than $230/year will start to impact their purchasing decisions.

Individual housing and feeding offers particular advantages over group housing. Monitoring of health and feed intake is much easier when individually housed. Vaccinations, artificial insemination, aggression reduction and other general observations are much easier to perform in an individual management system rather than group system.

It appears that a combination of methods may be required in order to maximize efficiency and wellbeing. For example, studies on hoop barns as a potential management option show that group housing is possible in conjunction with individual feeding stalls. During feeding, sows are placed in individual stalls where their health and feed intake can be monitored. At all other times the animals are free to interact and move around in a larger group setting. Cost analysis has shown that these structures can be cost competitive and offer advantages over individual housing units.
There is no one method that must or should be followed when managing sows. This allows freedom for producers to either construct new housing units or utilize existing facilities to maximize productivity and wellbeing. Pre-existing units can also be retrofitted to minimize capital investment while promoting wellbeing. A well thought out design will pay dividends in the long run. A producer looking to expand/begin operations would do well to have the foresight to anticipate the changes to come. Producers must consider the fact that several years down the road, major renovations may be required. It would be beneficial to consider a system that would be both profitable and adaptable for future change.

Animal housing is a complex issue which involves engineering, economics, ethics, and politics. The future is uncertain, but it appears that changes are on the horizon and coming quickly. Those who are not only able to adapt but also anticipate these changes will do well. It is no longer sufficient to find the least expensive option only when making decisions. Integration of social, political, and ethical concerns make decision processes much more complicated. It is for this reason that a broad knowledge is required, as well as the ability to make decisions based upon interdisciplinary studies. Challenges will no doubt appear in the future, but as the agriculture industry has shown before, these challenges provide the opportunity for innovation.
References


