2. Feeding and barn management strategies that maximize feed efficiency

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Abstract

The stockperson is responsible for the daily care and welfare of pigs in the barn. Through their actions, they also can influence overall feed efficiency. Prior to loading pigs, thoroughly cleaning and operating the facility in an all-in, all-out manner has shown to improve pig performance and feed efficiency. Removing feed from previous groups of pigs and repairing feeding and ventilation equipment influence closeout feed efficiency. When loading the barn, pigs should not be sorted into narrow weight categories. With weanling pigs, mat feeding can help increase feed consumption and reduce mortality immediately after weaning; however, prolonged mat feeding will result in feed wastage. After loading, daily chores that influence overall feed efficiency include individual pig treatment and timely euthanasia, ensuring water and feed availability, feeding the appropriate diet, managing the air quality and environmental temperature, properly adjusting feeders, and handling pigs in a positive manner. Removing a portion of the pigs from all pens during initial marketing events can result in feed savings while maximizing weight produced from the facility. Withdrawing feed prior to market also can result in feed savings. Proper handling during loading and transport to the processor to minimize mortality also can influence closeout feed efficiency. The stockperson can play a large role in improving overall feed efficiency by how they manage their day-to-day activities in the barn. This chapter will focus on these activities and their impact on feed efficiency.

Introduction

As discussed in other chapters, genotype, gender, market weight and dietary factors, such as energy and amino acid levels, diet form (e.g. pelleting or particle size), and additives (e.g. ractopamine) are the major drivers of differences in feed efficiency among production systems. However, many factors within production systems also lead to differences in feed efficiency.

Even after standardizing genetics, facilities, feeders, diets, weights and as many other variables as possible, feed efficiency and growth rate can remain highly variable within an individual production system. Once this variation is measured and noted, the question is how to reduce it.

For discussion of the actions that people in the barn can do on a day-to-day basis to influence feed efficiency, we will separate barn management into four phases of a barn turn that people in the barn can do: (1) prior to entry; (2) while loading the barn; (3) through daily chores, and (4) while unloading the barn at marketing time. Each of these four phases of barn management provides unique opportunities to influence feed efficiency. There are also some activities that are

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emphasized by some producers that are not as important as they believe. These action items that should be moved down the priority list or eliminated will also be discussed.

Prior to entry

The majority of modern swine production systems around the world manage their growing facilities on an all-in, all-out basis where all of the pigs are removed before another group of pigs enter the facility. This management style has greatly improved performance by decreasing horizontal transfer of disease from one group of pigs to the next (Cargill and Banhazi, 1998). All-in, all-out production also provides a unique opportunity for the barn manager to start anew with each group. The main areas for focus prior to entry are thoroughly cleaning the barn, maintenance and repair of equipment, and ensuring feed bins are empty before delivering new feed.

Thoroughly clean the barn

The primary objective of barn cleaning practices is to lower the dose of infectious pathogens that can be transmitted from one group of pigs to the next. Environmental contamination is an important contributor to bacterial and viral infections. For example, Davies *et al.* (1999) found that 27% (7/26) of samples obtained from a fully slatted finishing floor just prior to placement of pigs were found to be positive for salmonella. Cargill and Banhazi (1998) found that cleaning barns between groups of pigs was the most important component of all-in, all-out production. It led to improved pig performance and a greater reduction in respirable dust particles, viable bacteria counts, and gram positive bacteria counts than gained by adopting all-in, all-out production without cleaning barns (Table 1).

It has been well documented that animal performance is increased in 'clean vs. dirty' environments (Renaudeau, 2009). Pigs reared in a dirty environment had a 10% reduction in average daily gain (ADG) (0.78 vs. 0.87 kg) and 18% reduction in feed intake (1.86 vs. 2.28 kg) as compared with

Table 1. Influence of all-in, all-out management and cleaning between batches of pigs on growth performance and air quality measurements (adapted from Cargill and Banhazi, 1998).

Item[1]	All-in, all-out; cleaned	All-in, all-out; not cleaned	Continuous flow
Average daily gain (g)	658[a]	619[b]	610[b]
Airborne dust (mg/m^3)	1.80	2.31	2.51
Respirable particles (mg/m^3)	0.201[a]	0.265[b]	0.29[b]
Viable bacteria (CFU × 10^3/m^3)	132[a]	177[b]	201[b]
Gram positive bacteria (CFU × 10^3/m^3)	82[a]	109[b]	122[b]

[1] CFU = colony forming units.

[a,b] Groups without a common superscript letter differ at $P<0.05$.

pigs reared in a clean environment. The influence of sanitation on pig performance appears to impact feed intake and thus growth rate to a greater extent than feed efficiency.

Cleanliness is probably responsible for a large percentage of the growth performance benefits from all-in, all-out production (Amass *et al.,* 2001). Fortunately, most swine pathogens only survive for a brief amount of time outside the host in the absence of organic materials or moisture. Under experimental conditions, up to 99% of the bacteria can be removed by cleaning alone. Removal of visible organic matter removes 90% of bacteria from the environment. Another 6 to 7% of bacteria are killed by disinfectants with a final 1 to 2% killed by fumigation (Morgan-Jones, 1987). Letting the barn dry between washing and loading with pigs also plays a role in pathogen load. When we cannot let the facility dry, viruses have the opportunity to survive for extended periods of time. For example, PRRS can survive in water for up to 11 days; however, when dried it dies quickly (Pirtle and Beran, 1996).

When washing, one of the frequent errors producers make is not adequately cleaning feeders and waterers or not removing disinfectant and water from feeders or waterers. Because many feeders and waterers are not easily removed for cleaning, other methods must be used to remove water and dry them. Some producers use leaf blowers to remove the water from feeders and waterers that are not easily moved for cleaning.

Basic hygiene practices to decrease pathogen transmission from group to group include: (1) Building materials that are easy to clean. Rough surfaces such as concrete are more difficult to clean than smooth surfaces such as wire and plastic. Smooth nonporous surfaces will provide easier removal of fecal matter and faster drying. (2) Thorough cleaning and removal of organic matter such as feces and feed. In general, organisms are protected against disinfection agents by organic materials such as pus, serum, or feces. (3) Proper use of disinfectants including correct dilution and application. Diluting the disinfectant below its proper dosage or applying disinfectant to manure covered floors render it ineffective. (4) Lastly, proper downtime and drying of rooms is vital to minimizing pathogen load.

A survey of hygiene practices on 129 French farms indicated several practices associated with decreased residual contamination in nurseries (Madec *et al.,* 1999). The practices included dampening of the rooms immediately after moving the pigs out of the room. The researchers hypothesized that dampening prevented dying of the fecal matter and increased the ease and thoroughness of cleaning. Using a detergent was also recommended and associated with decreased residual contamination. However, in another study evaluating the impact of using a detergent, the researchers were unable to detect any impact on residual contamination after thorough washing (Kihlstrom *et al.,* 2001). This indicates that using a detergent may improve the ease of cleaning; however, if cleaning procedures are thorough, detergents may not impact the final amount of residual contamination.

Several other studies indicated that thorough cleaning and removal of organic matter resulted in less residual contamination (Amass *et al.,* 2001; Kihlstrom *et al.,* 2001). Additionally, greater distances between the surface of the slurry and the floor were associated with less residual contamination. The authors attributed this risk factor to splash back and recontamination during the cleaning process. Finally, factors associated with disinfectant usage such as proper dilution and application were important. Commonly available disinfectants vary widely in their ability to neutralize viruses such as porcine circovirus type 2 (PCV2; Figure 1). Royer *et al.* (2001) evaluated 11 commonly used disinfectants in swine farms and research laboratories. These included several disinfectant classes (products) tested: ethanol (alcohol), iodine (Weldol), phenol (1-Stroke, Tek-Trol), quaternary ammonium (Roccal D Plus, Fulsan), oxidizing agent (Clorox, VirkonS), alkali (NaOH), and chlorhexidine (Nolvasan). The mean titer after disinfection ranged from 5.2 for the chlorhexidine to 1.6 for the oxidizing agent VirkonS (log 10 scale). This compares to the control titer without disinfection of 6.0. The log 10 scale indicates that the reduction from 6 to 5 results in a 90% reduction, from 6 to 4 a 99% reduction, from 6 to 3 a 99.9% reduction and from 6 to 1 a 99.99% reduction of the virus. There are two important points to remember from this study:

1. PCV2 is a small enveloped virus similar to Parvovirus and thus, difficult to neutralize with disinfectants.
2. This study was conducted under controlled laboratory conditions and designed for maximum disinfectant activity. Disinfectant activity may be less effective in the field setting.

Although our knowledge on proper cleaning and disinfecting procedures for swine facilities is not complete, considerable research has improved our knowledge base in the past 10 years. In addition to the PCV2 disinfectant evaluation, this includes evaluation of farrowing house cleaning protocols, boot bath cleaning disinfectants and procedures, and methods to rapidly evaluate surface contamination in swine facilities (Amass *et al.*, 2001; Kelly *et al.*, 2001; Kihlstrom *et al.*, 2001; Amass, 2004; Martin *et al.*, 2008).

Maintenance and repair of equipment

The best time to conduct maintenance is when the barn is empty. Most good producers have a mental list of items that must be done between groups, but it is helpful to keep a log of items that need to be fixed, replaced, or serviced when the barns are empty. These could include items such as greasing bearings on augers or repairing waterers, gates, feeders, inlets, curtains, or insulation.

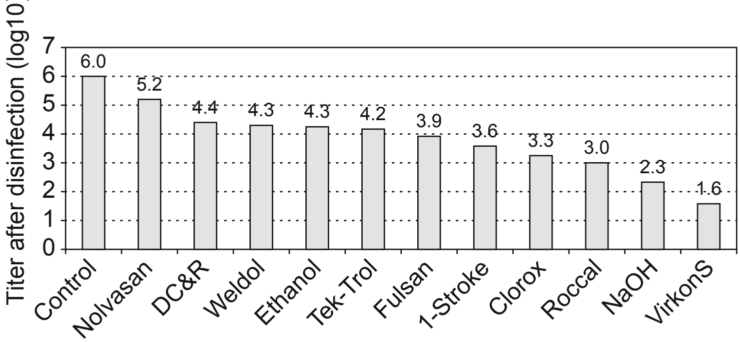

Figure 1. Reduction in infectivity of PCV2 after a 10 min disinfectant exposure (Royer et al.*, 2001).*

From a feed efficiency perspective, maintenance of feed handling is of utmost importance. This would include fixing any leaking feed bins, broken feed lines, feeder adjustment rods or other feeder parts (Figure 2). In order to understand the importance of proper maintenance on feed equipment, it may be helpful to consider the amount of feed passing through a single feeder or barn on an annual basis. For example, a 1,200 head barn with 48 pens (28 pigs per pen) will have 24 fenceline feeders. If feed efficiency is 2.8 and the pigs gain 100 kg during the finishing period, each pig would consume 280 kg of feed. Thus, 15,680 kg of feed would pass through each feeder and a total of 376,320 kg of feed would be used in the barn during a single turn. If 2.8 groups of pigs are fed in the barn each year, the quantity of feed passing through a feeder and through the entire barn increases to 43,904 kg and 1,053,696 kg, respectively. Thus, each feeder handles almost 44 tonnes of feed and over 1,000 tonnes are used in the barn annually. If diet cost is $280 per metric ton, the value of feed used per feeder and barn would be greater than $12,000 and $295,000 annually. Repairing feed handling equipment to save a small portion of this expense pays big dividends.

Other equipment, such as watering, ventilation, heating, and cooling equipment, also should be checked and repaired as needed. If pigs are above or below their thermoneutral zone because of equipment malfunctions, feed efficiency and growth rate will be negatively impacted.

Before pigs are loaded into the barn, equipment also should be checked to ensure the settings are correct for starting pigs. Ventilation controllers, temperature probes, fans, and curtains should be checked to make sure they are operational and that temperatures and ventilation are set for the

Figure 2. Feed spills.

appropriate number and weight of pigs. Before the pigs arrive, the barn should be pre-warmed if possible and be in the thermo neutral zone for the weight of the pigs. Feeders and feed drops should be adjusted as needed to ensure the feed is flowing to the entire length of the feeder. In some cases, feed drops are placed near the end of the feeder or too low in the feeder and the entire length of the feeder cannot be used by the pigs (Figure 3). Before pigs are placed, the proper diet should be in the feeders and all watering devices should be checked to ensure they are operating correctly and with adequate flow.

Ensure feed bins are empty

One consequence of phase feeding and all-in, all-out production is that feed for late finisher pigs is often left in the feeder after they are marketed. The lysine requirement for late finishing pigs is likely 40% lower than the requirement of the new pigs entering the barn. If a diet containing lysine levels typically fed to late finishing pigs is fed to lighter growing pigs, growth rate and feed efficiency can be 12 and 20% poorer, respectively, than if the pigs were fed to their lysine requirement (Friesen *et al.,* 1994). Thus, if low lysine, late finisher feed is left in the bin, growth rate and feed efficiency would be expected to be impaired at the beginning of the next group.

Cleaning of bins between groups of pigs also provides one of the only opportunities that producers have to ensure that feed buildup is not occurring on sides of bins. This buildup can be the source of mycotoxins, but can also lead to bridging, poor feed flow ability, and out of feed events after the subsequent group of pigs is placed.

Loading the barn

Sorting pigs

A common practice of many producers world-wide is to sort pigs by weight as they enter the facility to decrease variation within a pen. Although sorting to have uniform weight pigs in the pen is aesthetically pleasing, it is detrimental to pig growth performance (Gonyou *et al.* 1986b; O'Quinn *et al.,* 2001). Unsorted pigs have a wider weight range at placement, but grow faster than pigs that are sorted to be uniform in weight groups (O'Quinn *et al.,* 2001; Table 2). The reason for

Figure 3. Wrong placed feed drops preventing the use of the entire length of the feeder by the pigs.

this difference in growth performance is thought to be due to the increased aggression in pens with uniform pig weights as compared to pens with variable weight pigs (Francis *et al.,* 1996). Using individual pig weights within pens, O'Quinn *et al.* (2001) found that the medium weight pigs in the sorted pens grew slower than medium weight pigs in the unsorted pens. Although weight variation within a pen is less at placement when pigs are sorted into uniform groups, weight variation at market is similar to unsorted pens that have wide variation at placement (Tindsley and Lean, 1984; O'Quinn *et al.,* 2001).

There are legitimate reasons for sorting pigs, such as for split sex feeding or to feed the lightest pigs on one feed line and the heaviest pigs on another feed line. However, unless the pigs are split for these reasons, pigs should not be sorted when loading the barn. Pigs should be 'gate cut' into pens to allow the normal variation within each pen. As will be discussed later in this chapter, having the entire variation in pig weights within each pen also plays an important role in marketing as it allows pigs to be removed from all pens at the initial marketing event.

Stocking

During placement, another common practice in many production systems is to stock pens at a greater density than normal, in order to leave one or two pens (commonly referred to as 'pull' or 'hospital' pens) to allow for sick or unthrifty pigs to be sorted at a later time. Although this practice can help ensure that sick pigs receive proper access to feed and water and protection from pen mates, it can be troublesome from a performance standpoint if not handled correctly. For example, if too much space remains open and these 'pull' pens are not filled in a timely manner, pigs in the other pens will be overcrowded and performance will be reduced. Also, some feeders are designed to be shared between two pens with an open trough between the pens. These feeders can waste considerable amounts of feed if stocking density is much greater on one side of the feeder (regular pen) than the other ('pull pen').

Table 2. Sorting pigs at placement reduces overall growth rate and final body weight (adapted from O'Quinn et al., *2001).*

Item[1]	Sorted pens			Average[2]	Unsorted
	Heavy pens	Medium pens	Light pens		
ADG (g)	0.94	0.92	0.91	0.92	0.94
ADFI (g)	2.67	2.66	2.73	2.69	2.70
Feed:Gain ratio	2.85	2.93	3.02	2.93	2.88
Final weight (d 91) (kg)	123.4	117.8	113.2	118.1	119.9

[1] ADG = average daily gain; ADFI = average daily feed intake.

[2] Average of heavy, medium, and light pigs from sorted pens.

Mat feeding

When weaned pigs are loaded into a nursery or wean-to-finish barn, producers often mat feed to help pigs find feed after weaning and improve the transition to dry feed. When mat feeding, a small amount of feed (e.g. 500 g/pen) is placed on a board or mat. Feed is usually placed on the mat two or three times per day. When done correctly, mat feeding can improve growth performance and feed efficiency by reducing the number of 'fallout' pigs that fail to find feed immediately after weaning (Potter *et al.,* 2010). Because the only benefit of mat feeding is to help pigs find feed quickly after weaning, there is no benefit to mat feeding if it does not reduce morbidity or mortality. Providing too much feed or for too long a period can result in poor feed efficiency (Potter *et al.,* 2010).

Daily chores

Daily care and management of pigs in the barn is the greatest responsibility of a barn manager and an area where that person can have the greatest impact on feed efficiency. The herdsman has the responsibility to meet the daily needs of each individual pig every day. The basic needs of the pig can be simplified to feed, water, environment (air and temperature), and health.

Access to quality feed

In many production systems, the diet fed to pigs is controlled by someone other than the person in the barn. Feed budgets are often used to provide the appropriate quantity of each diet to pigs before they are switched to the next diet. Improper budgeting can lower pig performance, impair feed efficiency, and increase cost. By under-budgeting diets, pigs are fed below their amino acid requirement which will decrease pig performance (Main *et al.,* 2008). By over-budgeting diets, pigs are fed above their amino acid requirements which simply increases feed cost and reduces profitability (Main *et al.,* 2008). Many feed companies have tools available to assist with feed budgeting. A simple feed budget calculator is available at: www.KSUswine.org.

The first step in providing quality feed is ensuring that the correct diet was ordered and delivered from the feed mill. Also, the feed then must be made available to pigs in the barn. Feed access can be interrupted by a variety of manners, such as late delivery, bridging in feed bins, plugged feeders, or inadequate feeder space. Although the out-of-feed events can reduce growth performance, there is little evidence that they impact feed efficiency (Brumm *et al.,* 2008).

Design and adjustment of feeders

Feeder design and adjustment can influence feed efficiency. In 1989, Taylor and Curtis compared 11 nursery feeders to determine the degree of feed wastage. They found that feed wastage ranged from 1.7 to 11%. Relatively few studies comparing feeder designs have been published since that time. Gonyou and Lou (2000) compared 12 feeders selecting dry and wet/dry feeders that provided either a single or multiple feeding spaces. They found no difference in growth or feed efficiency between the single and multiple space feeder design. Pigs fed with wet/dry feeders had 5% greater ADG and average daily feed intake (ADFI) than pigs fed with dry feeders, but there was no difference in feed efficiency. Gonyou and Lou were testing classes of feeders and did not have enough replications of any one feeder to directly compare one feeder with another.

In order to understand proper feeder design, it is useful to consider how pigs waste feed while eating, their eating speed, and their space needs while eating. Gonyou (1999) determined that most feed wastage occurs during four main pig behaviors: (1) when feed falls from the pigs' mouth while they are eating, (2) as pigs back away from the feeder with feed in their mouth, (3) during fights at the feeder, and (4) while stepping in and out of the feeder. Thus, feeder designs and management strategies that minimize these behaviors will reduce feed wastage. For example, designs that decrease fighting and increase length of uninterrupted feeding bouts will reduce feed wastage. Designs that recapture feed that falls from the pigs' mouth and minimizes stepping in the feeder also reduce wastage. Full partitions that separate feeding spaces reduce pig-to-pig interaction during feeding and prolong feeding time (Baxter, 1991). Partitions also encourage pigs to stand perpendicular to the feeder (Baxter, 1991), which reduces the amount of feed that drops from the pigs' mouth to the floor and increases the amount that drops back into the feeder.

With meal (mash) diets, pigs fed with a wet/dry feeder eat faster than those fed with a dry feeder (Gonyou and Lou, 2000). This difference in eating speed is greatly reduced or eliminated when diets are pelleted. This is because eating speed is greater for pelleted diets than meal diets when fed in dry feeders. Thus, more feeder spaces are required for pigs fed meal diets in dry feeders than when fed pelleted diets or when fed mash diets in a wet/dry feeder.

The speed at which pigs consume feed dictates the maximum number of pigs that can eat from a single feeding space and, thus, the number of feeding spaces required for a pen of pigs (Gonyou, 1999). Using total eating duration and 80% occupancy rate, Gonyou (1999) estimated 11 to 12 pigs could be fed from each feeding space when fed meal diets from dry feeders. For wet/dry feeders with meal diets, maximum estimated stocking rate ranged from 10 to 15 pigs per space. These stocking rates are considerably greater than the traditional recommendations of 4 to 5 pigs per feeding space, but are supported by data from other studies (Bates *et al.,* 1993; McGlone *et al.,* 1993; Morrow and Walker, 1994).

The pigs' spatial requirements dictate the width and depth of the feeding space. Width of the pigs' shoulders dictates width of the feeding space. The desired width of the feeding space can be determined by adding 10% to shoulder width at the maximum pig weight. The shoulder width can be predicted by the equation (width, cm = 6.1 × BW, $kg^{0.33}$; Petherick, 1983). Thus, if pigs are marketed at 110 kg, feeder width should be at least 32 cm. If pigs are marketed at 130 kg, feeder width should be at least 34 cm. For pigs marketed at 150 kg, the width of the feeder space should be at least 35 cm. Feeder depth is dictated by the slope of the front of the feeder and size of the pig's head at their heaviest weight in the barn. For pigs marketed at greater than 120 kg, the depth from the front of the feeder lip to where feed exits the feeder should be at least 25 cm to allow pigs to eat comfortably while perpendicular to the feeder.

Even well designed feeders can waste feed if they are not properly adjusted. Liptrap *et al.* (1985) was one of the first to demonstrate that feed wastage was influenced by feeder plate setting. In three experiments, they found that feed wastage increased by 1.7 to 5.4% with increasing feeder opening. However, in all three of their experiments, daily gain also increased as feeder opening increased.

In nursery pigs, Smith *et al.* (2004) compared feeder openings of 9.2 to 31.5 mm for crumbled diets in a 6-space dry feeder (Table 3). These settings resulted in pan coverage ranging from 6 to 93%. A second criterion was to stock pens with 16, 20, and 24 pigs per feeder. As pan coverage increased, growth rate and final body weight increased with 11.8 mm opening (12.3% pan coverage) adequate when pens were stocked with 16 to 20 pigs; however, 17.9 mm opening (43.7% pan coverage) was required when pens contained 24 pigs. Interestingly, feed efficiency was not significantly influenced by feeder pan coverage; however, feed efficiency was 2.1% numerically poorer for the greatest pan coverage (93%) as compared to 12 to 44% pan coverage. These data demonstrate that the ideal pan coverage for optimal growth performance is greater than previously thought and is influenced by the number of pigs per feeder space.

Most of the grow-finish research has found similar responses to the nursery experiment with a greater impact of feeder adjustment on average daily gain than on feed efficiency. In four of the eight grow-finish experiments (Table 3), growth rate improved as feeder opening and, thus pan coverage, increased. Feed efficiency was only significantly improved in two of the experiments. The average numerical improvement in feed efficiency due to decreasing pan coverage was 2.9% with optimal pan coverage of approximately 40 to 60%.

Increasing pan coverage to increase growth performance appears to be more important with younger pigs (<70 kg; Myers *et al.*, 2010a; Bergstrom, 2011) than with older pigs. Extra pan

Table 3. Recent experiments determining the influence of feeder adjustment on pig performance.

Reference	Stage	Feeder type	Feed pan coverage (%)		Significant response[1]	Improvement in Feed:Gain ratio
			Min	Max		
Smith *et al.*, 2004	nursery	dry	6	93	ADG, ADFI	2.1%
Duttlinger *et al.*, 2008	finisher	dry	26	79	-	3.1%
Duttlinger *et al.*, 2008	finisher	dry	24	78	ADG	2.6%
Bergstrom, 2011 Exp. 1	grower	dry	9	79	ADFI	2.2%
Bergstrom, 2011 Exp. 1	grower	wet/dry	35	65	ADG, ADFI	-1.6%
Bergstrom, 2011 Exp. 2	finisher	dry	25	83	-	0.0%
Bergstrom, 2011 Exp. 2	finisher	wet/dry	53	82	ADG, ADFI	5.7%
Bergstrom, 2011 Exp. 3	finisher	wet/dry	63	83	ADG, ADFI	0.4%
Myers *et al.*, 2010a	finisher	dry	28	75	ADFI, F:G	3.9%
Myers *et al.*, 2010b	finisher	dry	43	87	ADFI, F:G	4.9%
Average improvement in finisher Feed:Gain ratio by decreasing pan coverage:						2.9%

[1] ADG = average daily gain; ADFI = average daily feed intake, F:G = Feed:Gain ratio.

coverage appears to have little impact on feed efficiency with younger, lighter pigs. Conversely, excess feeder pan coverage appears to have the greatest negative effect on feed efficiency with older, heavier pigs (Myers *et al.,* 2010a). The difference in response at different body weights may be due to the differences in eating speed. Younger pigs eat more slowly and require more total eating time than older pigs (Figure 4; Hyun *et al.,* 1997). The difference in eating speed means that younger pigs require more feeding time when stocked at the same density on the same feeder than older pigs. Thus, if the feeder is adjusted too tightly, they may not have enough time to work the feeder and thus cannot consume enough feed to maximize growth performance. Conversely, older pigs that eat faster have more time to work the feeder and consume their daily requirement. As reviewed by Brumm and Gonyou (2001), feed access appears to alter feeding speed with ranges of 22 g/min for a restrictive feeder (Walker, 1991) to 37 g/min for pigs eating from a more spacious feeder (Gonyou *et al.,* 1992).

Water availability

Water is often a forgotten or under-appreciated nutrient. Access to water appears to be the most critical factor with water flow rate and quality less important for growth performance and feed efficiency. Pigs are adept at adapting their drinking time based on flow rate to achieve their needed water intake. Numerous recommendations exist for minimum water flow rates; however, Brumm and Mayrose (1991) demonstrated that, even in summer heat without sprinkling for cooling, flow rate could be as low as 250 ml/min for finishing pigs with 22 pigs per nipple without altering growth performance. The low flow rates caused more social disruptions indicating that pig behavior was influenced, but pigs apparently adjusted their drinking time to maintain intake. From a practical perspective, flow rate should be 0.5 to 1 liter/min for 10 to 20 kg pigs and 1 to 2 liters per minute for finishing pigs (Defra, 2003).

For drinker numbers, a general recommendation is that one nipple drinker should be provided for every 15 pigs and one bowl drinker should be provided for every 30 pigs (Defra, 2003).

Figure 4. Eating duration (minutes per pig per day) as influenced by body weight (adapted from Hyun et al.*, 1997).*

Providing multiple drinkers in a pen reduces the possibility of limiting water intake when a drinker becomes plugged or somehow unusable.

Most recent research on water and water devices has centered on the impact on water waste and manure volume. In a series of experiments as reviewed by Brumm and Gonyou (2001), researchers demonstrated that providing water via wet/dry feeders reduced wastage compared with nipple drinkers; swinging drinkers reduced water use compared with nipple drinkers and bowl drinkers decreased water use compared with swinging drinkers. Although not directly compared in the same experiment, bowl drinkers and wet/dry feeders appear to have similar water use. They both also had the lowest water disappearance of the delivery devices tested. No differences in performance were found in most experiments except in one trial where pigs provided water through a bowl drinker had a slight improvement (2.49 vs. 2.55, $P<0.01$) in feed efficiency compared with pigs provided water from a swinging drinker. Patience *et al.* (2004) also demonstrated that nursery feed efficiency tended to be improved (1.49 vs. 1.54, $P<0.10$) with a bowl drinker compared with a nipple drinker. The reasons that feed efficiency would be improved with a bowl or cup drinker are not known.

Providing a clean water source is important as it can be a source of bacteria and viruses (Thacker, 2001). Standards for other water quality criteria have been set for total dissolved solids, pH, hardness, sulfates, nitrates, and other contaminants (Thacker, 2001). In reality, numerous studies have demonstrated that pigs adapt to even high levels of most of these other water measures with little impact on performance. However, many swine producers are often concerned with loose stool and diarrhea with poor quality water when pig performance is not affected (Thacker, 2001).

Manage the environment

The person in the barn has the greatest responsibility for daily management of air quality and environmental temperature. The impact of environmental temperature on feed intake and growth is well documented and covered in detail by Renaudeau *et al.* (2012; Chapter 9 in this book). In brief, as ambient temperature drops below the lower critical temperature, feed intake increases. Because of the increase in thermoregulatory requirement, feed efficiency becomes poorer. Nienaber *et al.* (1990) demonstrated that feed efficiency was 14% and 35% poorer for pigs housed at 4 or 11 °C, below their lower critical temperature, respectively, than pigs housed within their thermoneutral zone (2.75 vs. 3.14 vs. 3.72 F:G). Clearly, housing pigs below their lower critical temperature greatly increases feed intake and maintenance requirements which results in poorer feed efficiency.

Heat stress also can have a negative impact on feed efficiency due to the increased energy requirement for thermoregulation. In finishing pigs, growth rate is often affected to a greater extent due to hot temperatures than cold due to the negative impact on feed intake. In a meta-analysis, Renaudeau *et al.* (2011) mathematically described the relationship between temperature and pig performance at different body weights. From their data, the maximum ambient temperature before daily gain and feed efficiency are influenced can be calculated. These data indicate that daily gain is negatively affected before feed efficiency as temperature increases (Table 4). Their review indicated that the effect of temperature on daily gain is greater in today's pigs than those in the past. This indicates that genetic changes for increased lean growth may have led to pigs

Table 4. Maximum ambient temperature (°C) before daily gain or feed efficiency are impacted due to high temperatures.

Body weight (kg)	Daily gain	Feed efficiency
10	29.3	35.6
15	28.2	34.1
20	27.4	33.0
25	26.7	32.1
30	26.2	31.4
35	25.7	30.8
40	25.3	30.2
45	24.9	29.8
50	24.6	29.4
55	24.3	29.0
60	24.1	28.6
65	23.8	28.3
70	23.6	28.0
75	23.4	27.7
80	23.2	27.5
85	23.0	27.2
90	22.9	27.0

with reduced capacity to cope with heat stress. The daily reduction in gain for each degree Celsius increase in temperature from 20 to 30 °C was 12, 18, and 25 g/d for publications before 1990, 1990 to 1999, and 2000 to 2009, respectively for a 50 kg pig (Renaudeau *et al.,* 2011).

In modern swine facilities, high ambient temperatures are often a greater risk than low temperatures. Maintenance of fans, sprinklers, cool cells, and any other heat dissipation equipment is essential to minimize the effect of high ambient temperature on pig performance. Sprinklers must be checked, flushed, and if needed, replaced to ensure they are operational before summer temperature increases. Stir fans, maximum ventilation fans, and fan controllers also should be checked. It may be helpful to run all equipment simultaneously in all rooms of a facility to ensure that motors and the electrical system meet needs before high temperatures test their capabilities.

Besides temperature, there is increasing evidence that air quality affects pig performance. Data from Murphy *et al.* (2000) illustrates a negative relationship between airborne bacteria numbers and growth rate. This negative relationship was found in three separate analyses with different phases of production in the farm to farm comparisons; however, viable airborne bacteria concentrations were also correlated with stocking density differences across the farms making it difficult to totally separate the impact of stocking density and air quality. The evidence suggests that methods to lower airborne bacteria may improve pig performance. Recent commercial studies with electronic space charge systems (electrostatic particulate ionization) indicate that reducing airborne particulate matter lowers hydrogen sulfide and ammonia concentrations and increases pig performance. Several research studies in commercial poultry facilities and with experimental pathogen loads have validated the ability of these electrostatic space charge systems to lower dust, ammonia, and airborne pathogens (Ritz *et al.*, 2006). However, more studies under controlled environments are needed to verify these results in pigs.

Individual pig treatment and timely euthanasia

Another key job of the stockperson is to check each pig each day for signs of disease or discomfort and to ensure that they can easily access feed, water, and fresh air. Pigs showing signs of disease should be promptly treated as per veterinarian-client-patient relationship. Any pig that shows no sign of improvement or has no prospect for improvement after two days of intensive care should be humanely euthanized, unless there are special circumstances (National Pork Board, 2011). Any severely injured or non-ambulatory pigs with the inability to recover should be euthanized immediately. These guidelines are for the welfare of the individual pig, but also can serve to improve the welfare and limit mortality in other pigs by reducing the spread of infection. Reducing mortality through early detection and prompt intervention will improve feed efficiency of the overall group. Although the impact varies with timing of mortality in the finishing stage, each 1% increase in mortality worsens closeout feed efficiency by approximately 0.5%.

Pig handling

In addition to daily observation, the person in the barn also can dictate the level of fear that pigs have to human interaction. Several experiments have demonstrated that pigs that are fearful of humans due to repeated negative handling have poorer performance. In a four week study, Boyce *et al.* (2001) demonstrated that pigs exposed to negative handling (shocking the animal with a battery-operated electric prod if the pig approached the person) for 10 s per day had poorer feed efficiency (3.19 vs. 2.75) than pigs that received positive treatment (stroking the animal) with pigs that experienced no handling intermediate (2.89). The response was mainly due to a numerical reduction in daily gain for the negatively handled pigs.

Earlier research by Gonyou *et al.* (1986a) also demonstrated that similar minimal (no handling) or positive handling (kneeling and stroking the pig when it approached) had improved ADG and feed efficiency compared with pigs that received negative (approaching and touching pig on forehead with gloved hand) or adverse (shocking pigs with electric prod) handling. The negative effects were most pronounced during the first 3 weeks of the experiment with no difference between treatments during the last 4 weeks of their 10 week experiment. Hemsworth *et al.* (1987) found that alternating between pleasant and unpleasant handling resulted in similar performance to pigs that received continual unpleasant handling. Black *et al.* (2001) concluded that minimal human exposure appears to be the best treatment for maximizing growing pig performance under commercial conditions. Certainly, there is ample evidence that negative handling must be avoided, not only from a pig performance perspective, but an animal welfare perspective as well.

Unloading the barn

A barn manager can do an excellent job of managing pigs throughout the growing period, but their job is not completed until the pigs are marketed and the facility is cleaned and prepared for another group of pigs. The marketing strategy, length of feed withdrawal before market, and handling of pigs while loading and during transport also affects closeout feed efficiency.

Marketing pigs from all pens

Pig weight is the major factor influencing market price and gross revenues in a production system. Because individual pig growth rate varies, the range in weight from the lightest to heaviest pig within a barn can be over 50 kg at market. Therefore, pigs are often marketed over time. The heaviest pigs in the barn are sold first, allowing more space and time for lighter pigs to achieve the desired market weight. Removing the heaviest pigs from a pen increases the growth rate of remaining pigs in the pen (Woodworth *et al.,* 2000) with part of the response due to increased floor and feeder space (DeDecker *et al.,* 2005). The remaining portion of the response may be due to changing social dynamics when dominant pigs are removed from the pen.

After the first marketing event, improvement in the growth rate of pigs remaining in the pen will result in more total weight sold from the barn. This compensatory growth also results in feed savings as feed efficiency of pigs remaining in the barn is improved.

The magnitude of growth response to removing pigs from the barn appears to vary due to days that pigs remain in the barn and stocking density. DeDecker *et al.* (2005) removed either 25% (16 of 52 pigs) or 50% (26 of 52 pigs) of the pigs in a pen 19 d before market and found that growth rate and feed efficiency improved for the remaining pigs in the pen (Table 5). In their experiment, removing 25% of the pigs from the pen improved growth rate of remaining pigs to such an extent that total weight marketed per pen was greater than for pens without any pigs marketed on day 19. The improvement in feed efficiency led to a savings of 7.7 kg of feed per pig marketed when 25% of the pigs were removed 19 days before market. Removing 50% of the pigs led to further numerical improvements in performance of the remaining pigs and resulted in a savings of 23.9 kg of feed per pig; however, their compensatory growth was not enough to maintain total weight sold per pen.

Jacela *et al.* (2009) conducted two experiments to determine if removing a lower percentage of pigs than DeDecker *et al.* (2005) would elicit a similar benefit in subsequent performance. They observed that removing pigs 2 or 4 pigs from a pen of 25 pigs 15 days before marketing improved growth and feed efficiency resulting in overall feed savings without reducing total weight sold. In the second experiment, Jacela *et al.* (2009) tested several marketing strategies (Table 6). Starting with 25 pigs per pen, they marketed 2 pigs per pen 20 days before final marketing with an additional 2, 4, or 6 pig per pen (8, 16, or 24%) marketed 10 days later. All remaining pigs were marketed on d 20. Like DeDecker *et al.* (2005), Jacela *et al.* (2009) found that total weight sold per pen can be maintained and feed savings per pig increased when a portion of the pigs per pen are removed before the final market date.

Table 5. Influence of pen unloading strategy on pig performance and feed savings (adapted from DeDecker et al., *2005).*

Initial pigs per pen	52	52	52
Pigs removed	0	13 (25%)	26 (50%)
Space per pig after removal (m^2)	7.0	9.4	14.0
Initial pig weight (kg)	113.0	113.7	113.3
Initial weight of remaining pigs (kg)	113.0	110.5	105.8
Final weight of remaining pigs (kg)	126.0	126.5	122.2
Initial weight removed (kg)	0	1,623.1	3,176.9
Removed average weigth per pig (kg)	0	124.9	122.2
Marginal days on feed	19	19	19
Marginal average daily gain (g)	659	829	834
Marginal Feed:Gain ratio	4.24	3.76	3.63
Weight marketed per pen (kg)	6,536.2	6,556.4	6,334.6
Weight marketed per pig placed (kg)	125.7	126.1	122.2
Feed savings per pig placed			
kg per pen	-	401.1	1,244.5
kg per pig	-	7.7	23.9

Table 6. Influence of pen unloading strategy on pig performance and feed savings during the last 20 days prior to market (adapted from Jacela et al., *2009).*

Pigs/pen	25	25	25	25	25
Removed on d 0	0	2	2	2	2
Removed on d 10	0	0	2	4	6
Space/pig (m^2)	0.67	0.72	0.80	0.88	0.98
Total pen gain (kg)	458.1	465.8	459.0	445.9	442.3
Total pen feed (kg)	1,320.0	1,261.0	1,250.6	1,226.1	1,168.0
Total wt marketed (kg)	3,127.6	3,139.3	3,123.5	3,123.9	3,122.6
Marginal average daily gain (kg)	0.92	1.01	1.04	1.06	1.11
Marginal average daily feed intake (kg)	2.64	2.74	2.84	2.92	2.92
Marginal Feed:Gain ratio	2.88	2.71	2.73	2.75	2.64
Feed savings per pig placed					
kg/pen	-	59.0	69.4	93.9	152.0
kg/pig	-	2.4	2.8	3.8	6.1

To capture the growth and feed efficiency benefit for the greatest majority of pigs in the barn, a portion of the pigs should be removed from every pen at the initial marketing event. If certain pens have several pigs removed and other pens have none or very few pigs removed, the benefit will be limited to those pens where pigs were removed. Although we are focusing on the feed savings in our feed efficiency discussion, the value gained by increasing the weight of remaining pigs in the pen should not be overlooked. This weight gain is highly valuable for any producer marketing to a processor with discounts for lightweight pigs.

Feed withdrawal prior to market

Withdrawing feed from pigs before market will decrease weight of intestinal contents resulting in decreased risk of accidental laceration of the gastrointestinal tract during evisceration (Kephart and Mills, 2005; Frobose *et al.,* 2011). It can also significantly increase feed savings and carcass yield. However, care must be taken to not extend the feed withdrawal period too long or carcass weight will also be reduced.

In two experiments, Kephart and Mills (2005) tested feed withdrawal periods of 6 or 24 h (Exp. 1) or 6, 16, and 24 h before slaughter (Exp. 2). Feed withdrawal decreased feed intake in both experiments and resulted in an approximate feed savings of 2 kg/pig for 24 h withdrawal. To the contrary, they also found a 1 kg reduction in carcass weight with 24 h feed withdrawal in both experiments. The negative impact on carcass weight was not observed with 16 h of feed withdrawal, but feed savings were also not as great.

In two similar experiments, Frobose *et al.* (2011) tested withdrawal times of 7, 24, 36, and 48 h (Exp. 1) or 7, 12, 24, and 36 h (Exp. 2) before slaughter. Similar to the results of Kephart and Mills (2005), feed withdrawal led to important feed savings (Table 7). In contrast to the earlier trials, carcass weight was not reduced until feed withdrawal was greater than 24 h. From these data, it appears that feed withdrawal of 12 to 16 h can be safely used without reducing carcass weight. Extending the feed withdrawal past 16 h has the potential for greater feed savings, but may result in reduced carcass weight. Kephart and Mills (2005) also suggested that the negative effect of longer feed withdrawal times may be more pronounced in hot weather than in cold weather.

Withdrawing feed before market is easily implemented when selling the last loads of pigs in the barn; however, it is difficult to implement when other pigs remain in the barn. Special facility designs, such as sort barns, allow feed withdrawal to be practiced on all pigs marketed from the barn. Without these designs, pigs remaining in the barn are subjected to repeated out of feed events, which can lower weight gain of pigs remaining in the barn.

Handling pigs while loading

Mortalities that occur during the marketing process or during transport to the processor are more expensive to the producer than during any other stage of production. This is because 100% of production costs, including all feed, have been used with no value returned to the production system. In a review of 23 trials conducted in the USA, Ritter *et al.* (2009) found that losses at the processing plant were approximately 0.69% with 0.25% being from dead pigs and 0.44% from

Table 7. Effect of feed withdrawal on finishing pig carcass weight and feed savings (adapted from Frobose et al., *2011).*

	Feed withdrawal in hours			
	7	24	36	48
Experiment 1				
Yield (%)	74.4	76.1	76.3	76.4
Carcass weight (kg)	95.8	95.5	93.8	93.1
Feed savings (kg)	-	2.5	4.3	5.0
Experiment 2				
Yield (%)	75.3	75.5	76.1	77.0
Carcass weight (kg)	91.6	92.9	92.4	91.1
Feed savings (kg)	-	0.4	1.7	2.9

non-ambulatory pigs. The summary indicated an additional 0.11% of pigs were non-ambulatory losses at the farm. These losses were estimated to cost the USA pork industry over $46 million.

Although some transportation loss is unavoidable, proper handling and care during loading and movement will reduce such losses. Transport losses can be reduced by proper loading ramp and alley floor design, quiet handling with minimal or no use of electric prods, proper stocking density during transport, avoiding hauling during extreme weather conditions, and controlling ambient temperature in the transportation vehicle (Grandin, 2010). Moving market weight pigs in small groups (4 vs. 8 pigs) during loading reduced loading time, physical signs of stress during loading and unloading, and transport losses at the packing plant (Berry *et al.*, 2009). Procedures outlined in the National Pork Board's Transportation Quality Assurance Handbook (2008) should be followed when loading and transporting market pigs to minimize losses during the marketing process.

Conclusions

In conclusion, the stockperson is responsible for the daily care and welfare of pigs in the barn and can clearly influence feed efficiency for a group of pigs. From before loading the barn to implementing the final marketing program, stock people play a key role in determining success or failure of a group of pigs' performance. Key periods when their actions have the greatest impact on overall feed efficiency include: (1) daily care and treatment of pigs to minimize mortality; (2) proper maintenance and upkeep of feeding and ventilation equipment; (3) managing the environment temperature and air quality in the barn; (4) adjustment of feeders; and (5) implementation of the appropriate marketing strategy. Although other action items can influence growth and feed intake, the stockperson in the barn can have their greatest impact on feed efficiency by focusing on these areas.

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