Sponsors

University of Minnesota
College of Veterinary Medicine

College of Agricultural, Food and Environmental Sciences

Extension Service

Swine Center

Editors
W. Christopher Scruton
Stephen Claas

Layout
David Brown

Logo Design
Ruth Cronje, and Jan Swanson;
based on the original design by Dr. Robert Dunlop

Cover Design
Shawn Welch

Economics of space utilization

Joseph F. Connor, DVM

Space utilization is a key driver of pork systems. Producers need to maximize the amount of body weight gain that can be produced in a given facility within a specific period so facility cost per unit of pork produced can be optimized. Space utilization has the components of production (pounds per square feet) and economics (return on equity). A multitude of factors affect space utilization. Factors from the sow include weaning weight, percent of full value pigs, and weekly variation in pigs weaned. Factors in the growing phase include entry weight, entry age, fill-time, facility, space allocated, number of pigs per pen, equipment, location of feeders, location of waterers, slaughter weight, diets, diet additives and sanitation. Influences of space utilization that bridge both reproductive and growing phases include genetics, health, management, and variation. Historically, veterinarians have used pigs produced per year and pounds marketed per sow per year as the benchmark. A realistic goal is 6000 pounds per sow marketed per year. More recently, pounds or kilograms per square foot or square meter are being suggested as the benchmark. A realistic goal is 65 pounds marketed per square foot. In the future, pounds or kilograms of protein per square foot or square meter will be used. Most floor space recommendations and research studies have used individual daily gain, daily feed intake, and feed per gain as the performance criteria. To determine the efficiency of a given facility, daily gain per square foot or square meter and daily gain per daily feed intake per square foot or square meter are helpful.

Daily gain and daily feed intake increase as floor space per pig increase. Summary of references from this review of Powell and Brumm[1] resulted in this relationship in daily gain (DG) versus floor space (sq meter) per weanling (W), growing (G) and finishing phases (F).

$DG - W = 0.261 + 800S - 1.051S^2$; ($R^2 = 0.97$)
$DG - G = 0.489 + 0.520S - 0.2812S^2$; ($R^2 = 0.93$)
$DG - F = 0.398 + 0.704S - 0.340S^2$; ($R^2 = 0.69$)
Powell and Brumm developed these performance curves using data generated by University of Nebraska research.

Gain = $DG - F = 1.095 + .0152S$; $G < S < 12$
where DG – F is the daily gain in pounds (lb) for the finishing phase and S is the pen floor space per pig in sq ft.

Intake = $DFI - F^2 = 4.795 + .1138S$; $G < S < 12$
where DFI - F is the daily feed intake in lb for the finishing phase and S is the pen floor space per pig in sq ft.

These performance curves show that the maximum pig performance (ADG, ADFI, and F/G) occurred when pigs were given 0.76 sq ft in the grower and 12 sq ft in finishing. In the Powell and Brumm study, the revenue was maximized when pigs were allocated 4.2 sq ft in their grower and 6 sq ft in finishing, illustrating the active augment of space turnover.

Guidelines for floor area allowance should strike a balance between animal well-being as indicated by ADG and efficiency of space use (gain per unit of floor space). Gonyou and Samakarone[2] demonstrated that space allowance should be based on body surface area which is proportional to 0.667 BW.

Growth trials were conducted at Kansas State University[3] to evaluate 6, 8, 10, or 12 sq ft space allowance per pigs on the ADG, ADFI, and feed per gain. Pigs allowed 12 sq ft reached 250 lb 3.5 days sooner than those allowed 8 sq ft and 14 days sooner than those allowed 6 sq ft.

Increasing growth rate of the entire group will not reduce variation, but will increase the weight of the slow growing pigs and thus increase throughput. The following are areas of focus to improve growth rate of the entire group:

- genetics
- health
- ractopamine
- sows with high milk production
- high lactation feed intake
- increase energy density
- correct amino acid levels
- feeding in gestation to enhance litter weight or number of muscle fibers

Variation in market weight has a major influence on space utilization. Variation in growth rate forces producers to manage slaughter weights, which is driven by the average daily gain of the lower end of the distribution curve because it dictates when barns can be emptied and re-

Public Issues

filled and is the weight range most discounted by the packer. Increasing the weight gain of the smallest pigs in a group will reduce variation. Several procedures can be used to increase weight gain of the smallest pigs. These include split suckling, complete nursery diets, supplemental milk, or cross fostering of lightest pigs to higher producing sows. Donovan and Dritz[4] demonstrated that split suckling reduced ADG variation and thus, reduced the variation in weaning weight (2% lower CV). Wolter et al.[5] found supplying supplemental milk during the suckling phase can effectively increase weaning weight by about 0.9 kg/pig during hot weather. However, this weight difference increased during the nursery or finishing phase. Numerous trials with complete nursery diets have demonstrated increased weight gain in the nursery, but the advantage does not magnify during finishing. Variation in market weight can be divided into these areas:

- artificial reduction in variation
- methods of variation reduction
- managing variation without reduction

Many studies have verified that beginning weight is the best predictor of end weight whether it is birth, weaning, or end of nursery. Several strategies have been used by producers to minimize light pigs. Standard deviation of the average birth weight of the pigs to be 24% and the standard deviation of the average weight of the pigs at 20 weeks of age is also 24% of (Dewey et al RM 6213)[6].

Artificial reduction has focused on reducing visual variation within a litter or pen of pigs. The most common strategies are aggressive cross fostering in farrowing or sorting by size in the nursery or finishing. Continual cross fostering is a practice to reduce variation within the litter. At least two experiments have demonstrated that aggressive cross fostering will reduce the litter variation, but the growth rate of the entire group is reduced as well. This reduction in variation appears to be because of reducing growth rate of the fastest pigs, rather than increasing growth of the slowest pigs resulting in no net benefit in space utilization. If the co-efficient of variation (CV) is below 10% to 12%, efforts to further reduce variation have generally been unsuccessful. If the CV is above 12 %, variation can be reduced, but generally requires a major change to the production system.

Factors that have been identified to improve weaning weights (Dewey, RM 5453)[7] are the following:

- increasing birth weight by 1 kg increased weaning weight 1.7 kg
- increasing weaning age by 1 day increased weaning weight by 0.19 kg
- castrating pigs 1 day later increased weaning weight by 0.02 kg
- administering iron 1 day later increased ADG by 0.002 kg
- providing 1 nipple or bowl waterer per 10 head of nursery pigs

Increasing weaning age and reducing the variation in weaning age has an impact on pig weight and the variation in pig weight at the end of the nursery and finishing stages (Dritz et al.[8]). This data indicates that variation in weaning age is one of the biggest drivers of variation in the final market weight in swine farms. From this dataset the percentage of pigs in each weight category can be calculated (**Table 2**). Variation increases as average weaning age is reduced and younger pigs grow slower than older pigs. If pigs are weaned over a seven-day period, final market weight will include the variation caused by the age spread (younger pigs) and the variation in weight

Table 1: Space allowance on performance to an average pen weight of 250 lb.

	Space allowance, sq ft/pig			
	6	8	10	12
Overall[A]				
Average final weight, lb	249.6	250.2	252.9	250.3
Average number days on feed[B]	84.0	77.0	73.5	70.0
Average daily gain, lb[B]	1.42	1.58	1.68	1.69
Feed/gain	4.16	3.93	3.92	3.92

AEighteen pigs per pen with four pens/treatment, average initial weight 130 lb.
BLinear effect of space allowance ($P < .05$).

Table 2: Influence of weaning age (d) and weaning weight (lb) on nursery performance.[A]

	12 to 15 d		16 to 18 d		19 to 21 d			P value		
	Light	Heavy	Light	Heavy	Light	Heavy	SEM	Weight	Age	Wt x Age
d 0 to 28										
ADG, g	213	241	286	286	309	295	5	0.05	0.01	0.07
ADFI, g	309	331	381	395	395	409	9	0.04	0.01	0.79
Feed/gain	1.46	1.38	1.35	1.39	1.37	1.39	0.02	0.83	0.10	0.04

AEach number is the mean of 12 pens (21 pigs/pen) and pigs averaged 5.3 kg at weaning.

gain in each age group. Reduction in weaning age variation can occur by weaning multiple times per week. The frequency of weaning events is often limited by the system design, health, or transport. Farrowing crate utilization can be improved by increasing the percentage of sows containing lactating females by reducing the days from entry to farrowing to a farrow event. Restricting split weaning and bump weaning will increase weaning age. Many farms have added farrowing crates to increase weaning age.

In most systems, lightweights are pigs less than 220 lb. Most lightweight pigs at slaughter start out as the lightest pigs at birth. Attrition is the number of pigs that do not reach full-value market weight and are typically referred to as culls, dead, or lights. Attrition is a major factor in profitability. Disease is the primary contributor to attrition because it increases mortality, decreases rate of gain, worsens feed conversion, increases growth variability, and diverts nutrients from lean tissue deposition. The economics of minimizing attrition are given in **Table 4**.

- several strategies have been used by producers to minimize light pigs:
- snatch and save (Akey[9]) improves piglets' chances of good colostral intake
- identify problem pigs at birth by establishing a minimum birthweight (2.2 lb)
- maximize feed intake of lactating sows
- provide supplemental milk
- avoid sorting of pigs at entry to nursery and finisher except for "at risk" pigs
- topdress appetizer product for first three days post weaning[9]
- increase diet phases if fill time is less than one week
- control disease

In a trial by Brumm et al (2002)[10], the difference in interaction of nursery space allocations and grow-finish space allocations suggested the response to crowding during the grow-finish phase may depend in part on whatever pigs are mixed or sorted following movement to the nursery. Brumm and co-workers completed a study attempting to manage variation in nursery and grower-finisher by sorting and regrouping lightweight pigs. They concluded that the removal of lightweight pigs and remixing in separate pens does not improve pig performance or decrease variation at market weight.

Split-sex housing can reduce variation even though modern genotypes have less difference. Growing gilts separate from barrows reduces variation simply because barrows grow faster than gilts. A production system must be large enough to fill a barn or site with a single gender in one week or less.

Table 3: Fast II vs. total pigs based on Hormel kill sheet 4/21/03 – 9/26/03.

	1200-hd FAST II Wean-to-Finish (1150 pigs sold)	Total Pigs (37,089 pigs sold) 4/21/03 – 9/26/03	Difference	Value
Avg Carc	204	199.2	4.8	$1.49
Sort Loss	$ 0.17	$ 0.90	$ (0.73)	
Base Price After Discounts and Premiums	104.9%	101.6%	3.3%	$3.70
Red Box	94.0%	83.3%	10.7%	$1.00
Too light	1%	6%	-5.0%	
Too Heavy	1%	5.0%	-4.0%	
Too Fat	4%	7%	-3.0%	
$0.55 per carcass mkt.			Added per Pig Profit	$6.19

Table 4: The economics of minimizing attrition.

	Experiment 1				Experiment 2	
	10	20	40	80	18	108
Initial body weight	23.1	23.2	23.2	23.2	31.9	31.6
CV^A Initial	12.8	11.8	11.6	12.0	14.8	15.7
Final Body weight	96.2	97.2	95.5	94.9	106.6^x	104.9^y
CV^A Final	7.7	6.9	8.5	8.6	9.6	10.3

ACoefficient of variation
xyMeans within same row and experiment having different superscripts differ.

Public Issues

Table 5: Average distribution of daily gain and body weight for pigs at 14 and 20 weeks of age on nine commercial farms (kg)

	Mean	SD	CV	25th %	50th %	75th %
Birth Weight	1.76	0.42	24.0	1.45	1.72	2.00
Weaning weight	6.20	1.65	26.5	5.10	6.00	7.10
7 week weight	15.8	4.23	26.8	12.7	15.4	18.3
14 week weight	48.3	9.37	19.4	42.3	48.7	54.5
20 week weight	83.5	17.5	20.9	71.4	84.8	97.0
ADG 7-14 weeks	0.652	0.19	30.14	0.548	0.663	0.752
ADG 14-20 weeks	0.803	0.21	26.54	0.703	0.823	0.927

Health is an encompassing term that includes not only pathogens, but factors such as number of sources, location of facilities, and location of source herd. Disease affects variation, some examples include the following:

- Ileitis reduces ADG 6% to 20% in affected pigs.
- Respiratory disease can decrease ADG by 40%.

Segregated parity flow allows growing of gilt offspring separately from sow offspring. The reduction in variation occurs because of more uniformity entry weights and improvements in health status of offspring of both groups (Moore[11]). System factors that improve health are expected to reduce weight gain variation. Schinkel et al.[12] demonstrated that pigs reared in al all in/all out manner have less variation in growth rate and market weight than pigs reared in a continuous flow. The CV for all-in, all-out pigs was 7.5% and for continuous flow it was 8.8%.

Opportunity barns allow separation of the smallest pigs (5% to 25%) from the remaining population. Recent data from Schnickel[12] demonstrates that the smallest 20% of the pigs at birth grow significantly more slowly after weaning and are responsible for the majority of variation in pig weight at various ages after weaning[8] In some systems, pigs are grown in an entirely different nursery and finisher while other pigs are simply separated in a different barn or room.

Reducing variation by selecting sires with similar indexes or by using fewer sires will reduce variation in market weight, but the impact will be small. Dr. Allan Schinckel indicated that sires account for only one-quarter of the genetic variance. Selecting sires with similar ADG EBVs with an accuracy of 0.5 will reduce CV to 96.875% of original. If market weight CV was 12%, it would be reduced to 11.625%. Thus, 95% of pigs with a mean weight of 260 lb will be in a market weight range of 199.6 lb to 320.5 lb instead of the original range of 197.6 lb to 322.4 lb.

Phase feeding variation in final weight is primarily influenced by energy. Including fat (5% to 6%) to a corn-soy diet will increase total weight gain by 3 to 5 kg. If you fed high energy diets to the lightest 50% of the pigs in a group, you could effectively increase weight gain by 2.5 kg to 5 kg compared to no increase in energy density.

Providing adequate water access has been shown to reduce variation as compared to insufficient water access (Dewey et al.[13]).

Inclusion of feed grade antibiotics may reduce variation in final market weight (Tillman and Green[14]), but the impact appears to be small. Health status has a profound impact on weight variation at market. Paylean inclusion (4.5 grams per ton) the last three weeks prior to slaughter increases weight per pigs marketed by 4 lb to 8 lb which shifts the average of the group.

Weight discount windows are determined by your packer matrix. In some areas producers can market to multiple packers or to packers with wide weight windows, which improves facility utilization.

In summary, a multitude of factors influence space utilization. Optimization of space occurs when the system manages a high percentage of these factors over a long time period.

References

1. Powell, Timothy A. and Michael C. Brumm 1999. Economics of Space Allocation for Grower-Finisher Hogs. As cited in RM #4543.
2. Gonyou, Harold W. and Thusith S. Samakarone 2003. Effects of large group sizes on performance of grower-finisher pigs. Carthage Veterinary Service, Ltd. 13th Annual Swine Conference.
3. Kansas State University 1990. Space Requirements of Finishing Pigs. Swine Update. As cited in RM #684.
4. Donovan, T.S. and S.S. Dritz .2000. Effect of split nursing on variation in pig growth from birth to weaning. J. Amer. Vet Med. Assoc. 217:79-81. As cited in RM #5685.
5. Wolter, B.F. et al. 2002. The effect of birth weight and feeding of supplemental milk replacer to piglets during lactation on preweaning and postweaning growth performance and carcass characteristics J. Animal Science. 80: 301-308. As cited in RM #6864.
6. Dewey, Cate et al. 2001. Effect of pig management on weight variation in grower-finisher pigs. American Association of Swine Veterinarians. As cited in: RM #6213.

7. Dewey, Catherine E. et al 2000. Variation in Weight Gain. As cited in RM #5453.
8. Dritz, Steve et al 2004. How to Increase Profit in Nursery (Site 2) and Grow Finisher Pigs (Site 3). Swine Profitability Conference.
9. Akey 2002. Strategies to Reduce the Incidence of Lightweight Pigs. As cited in RM #7006.
10. Brumm et al 2002. Effect of removal and remixing of lightweight pigs on
performance to slaughter weights. As cited in RM #6986.
11. Moore, Camille 2004. Components of Parity Segregation. National Hog Farmer. As cited in RM #8516.
12. Schinckel, Allan P. et al 2003. The growth performance of the progeny of two swine sire lines reared under different floor space allowances. J. Animal Science. 81: 1126-1135.
13. Dewey, Cate et al. 2001. Grow/Finish variation: cost and control strategies. American Association of Swine Veterinarians. As cited in RM# 6189.
14. Tillman, Paul B. and James D. Green 1996. Effect of BMD on End-weight Variation in Grower-Finisher Swine. American Association of Swine Practitioners. As cited in RM #2322.