The effects of feed particle size on swine production

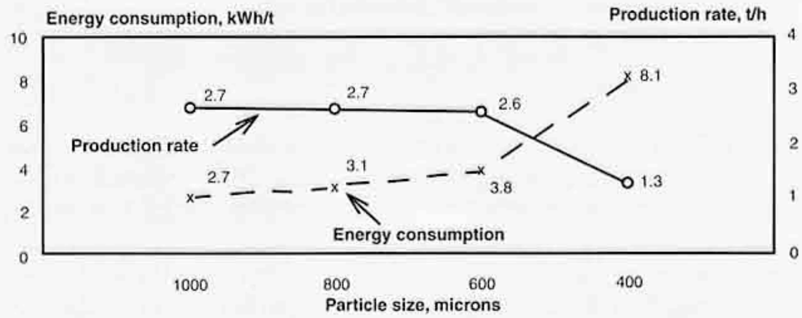
This article is Part I of the paper, "The effects of feed processing and diet modifications on swine production," by Joe D. Hancock, Kelly J. Wondra, Steve L. Traylor and Ioannis Mavromichalis, Departments of Animal Sciences and Industry and Grain Science and Industry, Kansas State University. The paper was presented at the 1996 12th Annual Carolina Swine Nutrition Conference, Raleigh, NC.

The U.S. livestock industry has been somewhat "spoiled" throughout the years by relatively cheap energy and protein feedstuffs. However, high production costs over the past year have stimulated producers to reevaluate most aspects of their livestock operations. High corn prices have focused interest on the use of alternative feedstuff and diet modifications that might help decrease cost of gain.

This paper will review research, recommendations and strategies that can help control diet costs. Particular attention is given to activities at Kansas State University (KSU) targeting optimized feed processing practices and diet formulations that can be used to improve swine production profitability.

Grinding

The first step in diet preparation is generally ingredient particle size reduction. To a large extent, the cost of reducing particle size is dictated by the energy required to mill a given quantity of grain, and the production rate per horsepower hour when grinding.



In research at KSU, Wondra et al. (1995b) milled corn with a hammermill to mean particle sizes of 1,000, 800, 600 and 400 microns. Milling energy increased slightly (from 2.7 to 3.8 kWh/ton) as particle size decreased from 1,000 to 600 microns (Figure 1). However, the energy required to reduce particle size to 400 microns was more than twice (8.1 kWh/ton) that required to mill corn to 600 microns. Production rate also decreased slightly as mean particle size decreased from 1,000 to 600 microns, compared to a marked decrease when milling to 400 microns.

In another experiment (Healy et al., 1994), milling data were collected from corn and two sorghum varieties (hard and soft endosperm varieties) ground to mean particle sizes of 900, 700 and 500 microns with a three-high roller mill. Results demon-

Table 1. Effects of corn particle size on nutrient metabolism in second-parity sows[a]

Item	Particle size, microns 1,200	900	600	400
DM digestibility, %[b]	82.2	85.2	85.6	88.1
N digestibility, %[c]	80.7	85.6	86.9	88.5
Biological value, %	55.0	62.7	62.0	57.0
N retention, g/d[c]	50.9	63.0	63.3	56.7
GE digestibility, %[b]	81.9	85.5	86.3	89.9
GE retention, Mcal/d[b]	13.2	14.1	14.4	14.3
DE, kcal/kg of diet[b]	3,513	3,668	3,705	3,857
ME, kcal/kg of diet[b]	3,399	3,572	3,601	3,745

[a] *From Wondra et al. (1995d). All values are apparent.*
[b] *Linear effect of particle size reduction (P<.02).*
[c] *Quadratic effect of particle size reduction (P<.04).*

strated that corn required more energy to grind and had a slower production rate than either sorghum grain. Indeed, less energy was needed to grind the sorghums to 500 microns than to grind the corn to 900 microns.

When Healy applied the milling costs suggested by McEllhiney (1986) to the milling data, he accounted for the variable cost of electricity and the fixed costs of depreciation, interest, taxes, insurance, maintenance, repairs and labor. The total milling costs ranged from $.64/ton for hard sorghum milled to a mean particle size of 900 microns, to $5.98/ton for corn milled to a mean particle size of 500 microns. Both sorghum grains were milled to 500 microns with less expense than corn milled to 900 microns.

To determine the changes in nutritional value that might result from decreased mean particle size of the cereals, the milled grains were substituted on a weight-per-weight basis into diets for nursery pigs. The diets were fed to 240 pigs in a 35-day growth assay. Analyses of costs indicate that as particle size was reduced from 900 to 500 microns, diet costs were more than offset by improved gain efficiency; cost per 100 kg of gain decreased for all three cereal grains as particle size decreased.

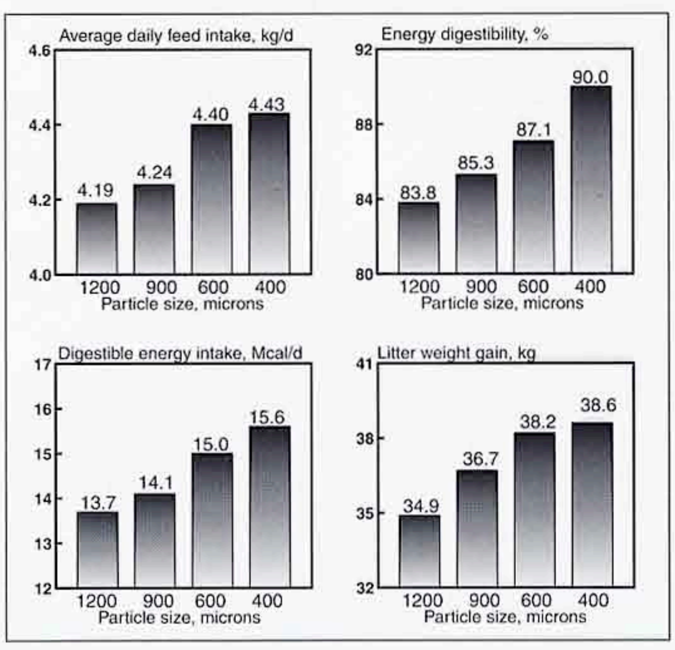


Figure 2. Effects of corn particle size on lactation performance of primiparous sows and apparent digestibility and intake of energy. (From Wondra et al., 1995e.)

Benefits of milling

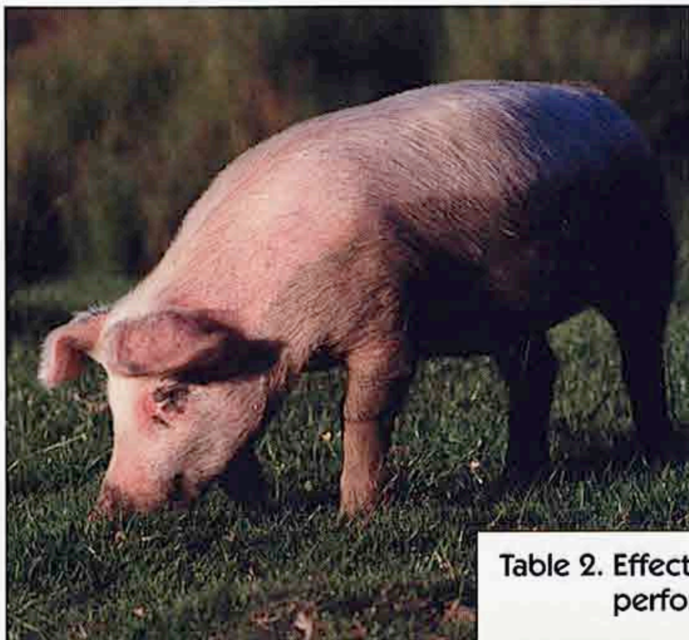
Improved animal performance is the most visible and easiest benefit of particle size reduction to measure. A few experiments indicate improved rate of gain, but improvements in efficiency of gain are more typical.

In the work by Wondra et al. (1995b) for corn ground to particle sizes ranging from 1,000 to 400 microns, an 8% improvement was observed in gain/feed for finishing pigs. Indeed, data from several experiments indicate a 1.3% improvement in gain/feed for growing pigs per 100-micron reduction in mean particle size in diets with corn particle sizes ranging from 1,200 to 400 microns.

The benefits of proper milling also apply to sows. Wondra et al. (1995e) conducted a lactation experiment using 100 primiparous sows fed diets with corn milled to four particle sizes (1,200, 900, 600 and 400 microns). The researchers were concerned that the diets with finely ground corn would not be palatable. However, feed intake actually increased as corn particle size was reduced (see Figure 2, page 38). This increased feed intake and marked increases in nutrient digestibility resulted in 14% greater intake of digestible energy (DE) and 11% increase in litter weight gain. Finally, because of the improved digestibility of nutrients with the reduced particle size, a 21% decrease in fecal excretion of dry matter (DM) and a 31% decrease in fecal excretion of nitrogen (N) occurred.

Data from several experiments indicate a 1.3% improvement in gain/feed for growing pigs per 100-micron reduction in mean particle size . . .

To determine the effects of reducing particle size of cereal grains on nutrient metabolism during lactation, 38 second-parity sows were fed corn-soybean meal-based diets, with the corn ground to



1,200, 900, 600 and 400 microns (Wondra et al., 1995d). The results indicate greater digestibilities of DM, N and GE as corn particle size was reduced from 1,200 to 400 microns (Table 1). Digestible energy and metabolizable energy (ME) values were maximized with the diet containing 400-micron corn. Indeed, the ME concentration of the diet was increased from 3,399 to 3,745 kcal/kg as corn particle size was reduced from 1,200 to 400 microns. To achieve the same increase in energy density with diet formulation methods, a 9% addition of soybean oil would be needed. Biological value and N retention increased as particle size was reduced from 1,200 to 600 microns, but decreased as particle size was further reduced to 400 microns.

This decrease may have resulted from the corn's amino acid profile. As a protein source, corn is deficient in lysine, threonine, tryptophan and valine, yet exceeds the requirements for other amino acids, such as leucine (NRC, 1988). The amino acid composition of soybean meal complements that of corn very well. However, by increasing only the corn's digestibility, diets would be high in digestible nonlimiting amino acids. The N from those excess amino acids would be excreted in the urine, thereby decreasing BV and percentage N retention.

Thus, in experiments with nursery pigs, finishing pigs and lactating sows, KSU data indicates an optimum particle size of 600 microns or less for cereal grains.

Mix uniformity

Inadequate mixing is the major cause of lack of diet uniformity. From a feed manufacturing viewpoint, the optimum mixing procedure requires minimal inputs of time, electricity and labor. Thus, a standard is needed to indicate adequate (but minimal) mix uniformity. That standard typically is a coefficient of variation (CV) for the distribution of some nutrient or marker within the feed. A CV of 10% or less has been suggested by Beumer (1991), Lindley (1991) and Wicker and Poole (1991) as representing an adequately mixed feed batch.

McCoy et al. (1994) at KSU conducted a series of experiments to evaluate the effects of mixer revolutions (mix time) on diet uniformity and growth of broiler chicks. A corn-soybean meal-based diet was mixed for different times to represent poor, intermediate and high uniformity. Analyses of the diets indicate a decrease in diet variability as mixer revolutions increased (see Table 2, page 40). The majority of the improvement occurred as the number of mixer revolutions increased from five to 20, with relatively small improvements as mixer revolutions were further increased to 80. However, there were substantially different CVs for diet uniformity at each mix time depending on the marker used for analyses; e.g., results for the high-uniformity treatment ranged from 9.7% to 22.8% for C1 concentration vs. Na concentration, respectively.

Table 2. Effect of mixing time on diet uniformity and performance of broiler chicks[1]

	Revolutions					
Item	5	20	80	SE	Linear[2]	Quadratic[3]
Chloride CV, %[4,5]	40.5	12.1	9.70	3.4	.001	.001
Red particle CV, %[4,6]	53.4	16.6	11.3	4.0	.001	.001
Blue particle CV, %[4,7]	53.9	17.0	10.6	3.5	.001	.001
Sodium CV, %[4,8]	44.5	23.2	22.8	3.1	.001	.001
Avg. daily gain, g	23.6	30.0	30.3	1.7	.050	.040
Avg. daily feed intake, g	43.1	51.5	52.7	2.9	.070	.100
Gain/feed	.548	.583	.575	.018	.170	.060
Mortality, %	12.0	0	0	5.8	.280	.220[1]

[1] *Ten cages per treatment; five birds per cage; avg. initial body weight was 37 g (Adapted from McCoy et al., 1994).*
[2] *Probability for linear effect of mixer revolutions.*
[3] *Probability for quadratic effect of mixer revolutions.*
[4] *CVs were calculated from analyses of the 10 bags assigned to each cage. The CV for each cage was then used for statistical analyses such that the means result from 10 observations (cages) per treatment.*
[5] *CV for C1 concentration (Quantab assay).*
[6] *CV for red iron particles (Microtracer assay).*
[7] *CV for blue iron particles (Microtracer assay).*
[8] *CV for sodium (Omnion assay).*

Table 3. Effects of mix time on diet uniformity and growth performance of nursery pigs[a]

Item	Mix time, min				Probability value, P<			
	0	.5	2	4	SE	Linear	Quad	Cubic
CV for Cr, %[b]	106.5	28.4	16.1	12.3	N/A[c]	N/A	N/A	N/A
ADG, g	267	379	383	402	18	.01	.02	.01
ADFI, g	598	711	701	720	22	.01	.08	.02
Gain/feed	.446	.533	.546	.558	.017	.01	.03	.02

[a] A total of 120 weanling pigs (avg. initial body weight of 5.5 kg) with five pigs/pen and six pens/ treatment (adapted from Traylor et al., 1994).
[b] Coefficient of variation for Cr was determined from 10 samples for each batch of feed.
[c] Not applicable for mix analyses.

As for chick growth performance, quadratic responses were observed for average daily gain (ADG), average daily feed intake (ADFI) and gain/feed; growth performance was improved as mix uniformity increased from poor to intermediate, with no further improvement as mixer revolutions increased to yield high uniformity. Thus, CVs of 12% to 23% (depending on the marker used) gave maximum growth performance, which is in sharp contrast with the current industry recommendation that the CV must be 10% or less, regardless of the marker used.

Traylor et al. (1994) conducted similar experiments with nursery and finishing pigs. For the nursery experiment, 120 weanling pigs (5.5-kg average initial body weight) were used in a 27-day growth assay. Treatments were mixing times of 0, 0.5, 2 and 4 minutes in a double-ribbon mixer. Increased mix time from 0 to 0.5 minutes decreased the CV for Cr (chromic oxide was the marker used in this experiment) concentration from 106.5% to 28.4% (Table 3). Diet uniformity improved further as mix time was increased to 4 minutes (i.e., a CV of 12.3%).

As for the effects on pig growth performance, ADG and gain/feed increased markedly as mixing time increased from 0 to 0.5 minutes, and continued to increase at a lesser rate as mixing time increased to 4 minutes (i.e., a quadratic effect). Nonetheless, the data indicate that nursery pigs needed a CV of no more than 12% to maximize growth performance.

For the finishing experiment, 128 pigs (56-kg average initial body weight) were fed to a 118-kg slaughter weight. The pigs were fed a corn-soybean meal-based diet with the same mix time treatments used in the nursery experiment. Growth performance was not affected by reducing the CV of the diet from nearly 54% to less than 10% (Table 4). Carcass backfat thickness decreased as mixing time was increased from 0 to 0.5 minutes, but plateaued as mixing was increased further. Bone strength did not differ among pigs fed the various treatments.

These data indicate that growth performance in finishing pigs was not affected significantly by CV of diet uniformity as great as 54% although, numerically at least, the lowest ADG and gain/feed and fattest carcasses were for pigs fed the diet with 0-minute mix time (i.e., a CV of 54%). These two experiments suggest that increased mix time improved diet uniformity and performance of nursery pigs, but finishing pigs were much less sensitive to diet nonuniformity.

In conclusion, growing animals are probably less sensitive to diet nonuniformity than once thought, with CV (Quantab and chromium analyses) of 12% being adequate for broiler chicks and nursery pigs and CV of at least 15% (and probably higher) being adequate for finishing pigs. However, commercial feed manufacturers should still exercise caution to produce uniform diets, particularly those containing feed additives, such as antibiotics, that may be subject to testing by regulatory agencies. FG

Part II of this article will focus on pelleting's effects on swine performance.

Table 4. Effects of mix time on diet uniformity and growth performance of finishing pigs[a]

Item	Mix time, min				Probability value, P<			
	0	.5	2	4	SE	Linear	Quad	Cubic
CV forsalt, %[b]	53.8	14.8	12.5	9.6	N/A[c]	N/A	N/A	N/A
ADG, g	777	807	793	787	15	--[d]	--	--
ADFI, kg	2.95	2.90	2.89	2.88	.05	--	--	--
Gain/feed	.263	.278	.274	.273	.005	--	--	.13
Dressing percentage, %	73.7	73.3	73.1	73.0	.2	.04	--	--
Fat thickness, mm	30.5	27.6	28.9	29.9	.5	--	.04	.01
Bone strength, kg of force	230	236	239	218	10	--	--	--

[a] A total of 128 pigs (avg. initial body weight of 56.3 kg) with eight pigs/pen and four pens/ treatment (adapted from Traylor et al., 1994).
[b] Coefficient of variation for salt was determined from 10 samples for each batch of feed.
[c] Statistical procedures were not applicable for mix analyses.
[d] Dashes indicate P>.15.

Reprint courtesy of FEED & GRAIN Magazine