

Kansas Agricultural Experiment Station Research Reports

Volume 0
Issue 10 *Swine Day (1968-2014)*

Article 1032

2005

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Recommended Citation

Groesbeck, C N.; Neill, C R.; Goodband, Robert D.; Tokach, Michael D.; Nelssen, Jim L.; DeRouchey, Joel M.; and Dritz, Steven S. (2005) "Inadequate diet mixing time reduces nursery pig performance," *Kansas Agricultural Experiment Station Research Reports*: Vol. 0: Iss. 10. <https://doi.org/10.4148/2378-5977.6872>

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INADEQUATE DIET MIXING TIME REDUCES NURSERY PIG PERFORMANCE

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Summary

Although the importance of thoroughly mixing diets is often emphasized, little data is available to quantify the impact of inadequate mixing on pig growth performance. Therefore, a 28-d trial was conducted to evaluate the effects of mixing time on growth performance of nursery pigs. A total of 180 weanling pigs (13.9 ± 1.8 lb BW, 21 ± 3 d of age) were used, with 6 pigs per pen and 6 pens per treatment. Experimental treatments consisted of mixing a diet for 0, 30, 60, 120 or 330 s in a horizontal ribbon mixer. Diets were fed in two phases (d 0 to 14 and 14 to 28), with diets in both phases containing relatively large amounts of low-inclusion ingredients such as synthetic amino acids, zinc oxide, and phytase. Diets in Phase 1 also contained 3.75% fish meal and 15% dried whey. Eight samples were collected from the mixer at the completion of the mixing time for each batch of feed to determine a coefficient of variation (CV). Each bag (50.0 lb) was labeled (first to last) and sampled to determine the degree of mixing that occurred as feed was conveyed from the mixer to the bagger. Each pen of pigs was then assigned a bag of feed. Bags were distributed in the order bagged (1, 2, 3, etc.). As feed was needed, the next chronological bag of feed was then added. Mixer CV values were 178, 38, 26, 21, and 5% for Phase 1 and 172, 79, 60, 48, and 26% for Phase 2 as mixing time increased. Bag CV values were 26, 20, 16, 11, and 7%

for Phase 1 and 56, 45, 40, 33, and 12% for Phase 2 as mixing time increased, indicating the degree of mixing that takes place as feed is conveyed from the mixer to the bagger. Growth performance was improved as mixing time increased (linear, $P < 0.01$) in both phases. From d 0 to 28, increasing mix time increased (linear, $P < 0.01$) ADG (0.73, 0.89, 0.90, 0.94, and 1.02 for 0, 30, 60, 120, and 330 s, respectively). Increasing mixing time also improved F/G (linear, $P < 0.01$; quadratic, $P < 0.07$; 1.55, 1.40, 1.32, 1.33, 1.30 for 0, 30, 60, 120, and 330 s, respectively). With greater use of low-inclusion ingredients such as synthetic amino acids in swine diets, these data demonstrate that inadequate mixing reduces nursery pig performance.

(Key Words: Growth, Mixer Efficiency, Nursery Pig.)

Introduction

The importance of thoroughly mixing diets is often emphasized to swine producers, but there is little data available to demonstrate the impact of inadequate mixing on pig growth performance. Feed uniformity may have a greater impact on growth performance than in the past due to changes in genetics, diet complexity, and the increased use of low-inclusion ingredients such as synthetic amino acids, phytase, antibiotics, and concentrated vitamin and trace mineral premixes. An

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adequately mixed batch of feed has been defined as a mixture that has a coefficient of variation (CV) of 10% or less. There is little data available to suggest that this CV value is appropriate for maximizing growth performance of pigs. Therefore, the objective of this study was to evaluate the effects of mixing time and CV on the growth performance of nursery pigs fed diets containing high concentrations of low-inclusion ingredients.

Procedures

A total of 180 weanling pigs (initially 13.9 ± 1.8 lb BW, 21 ± 3 d of age) were used, with 6 pigs per pen and 6 pens per treatment. Pigs were randomly allotted to pens and were blocked by weight. Experimental treatments consisted of mixing a diet for 0, 30, 60, 120, or 330 s in a 1.5-ton horizontal ribbon mixer. Diets were fed in two phases (d 0 to 14 and 14 to 28), with diets in both phases containing high concentrations of low-inclusion ingredients such as synthetic amino acids, phytase, and zinc oxide (Table 1). Diets in Phase 1 also contained 3.75% fish meal and 15% dried whey. All diets were fed in meal form and were manufactured at the Kansas State University Animal Sciences and Industry Feed Mill.

Each batch of feed (700- and 1,200-lb batches for each mixing duration in Phase 1 and Phase 2, respectively) was manufactured by following a step-by-step diet-mixing procedure. Corn was added to the mixer, and the mixer was turned on to distribute the corn across the bottom of the mixer. The mixer was then turned off for all additional ingredient additions. Soybean meal was added, followed by the remaining ingredients according to inclusion rate (largest to smallest). The micro additions were all pre-weighed into a barrel and added as a micro addition after all other ingredients. The mixer

was then sampled (0 s) or turned on for the specified amount of mixing time (30, 60, 120, or 330 s). Eight samples were collected from the mixer at the completion of each mixing time for each batch of feed to determine a CV for salt by using a grain probe. The batch was then discharged from the mixer and conveyed to the bagger. The discharge time was approximately 65 s for Phase 1 and 100 s for Phase 2. The discharge time was not included in the experimental treatment mixing time. At the bagger, each bag (50 lb) was labeled (first to last) and sampled with a grain probe to determine the degree of mixing that occurred as feed was conveyed from the mixer to the bagger. The bags were assigned to a pen of pigs and distributed in the order bagged (1, 2, 3, etc.). As feed was needed, the next chronological bag of feed was then added. The feeding procedure was designed to reproduce a situation similar to how a commercial auger system may distribute feed to feeders.

Each of the five dietary treatments was analyzed for mixer efficiency CV, from the samples collected from the mixer at the conclusion of mixing and from the samples collected from each bag after discharge from the mixer, by using Quantab[®] chloride titrators (Environmental Test Systems, Elkhart, Indiana; Table 2). There are two mixer-efficiency CV values for each diet and for each phase of feeding. Calculation for mixer efficiency CV was conducted with 12 samples collected from the bags for Phase 1 and 22 samples collected from the bags for Phase 2. Crude protein was also analyzed on each sample collected from the bags to evaluate variability in diet CP with increased mixing time (Tables 3 and 4).

Results and Discussion

Increasing the mixing time improved mixer-efficiency CV (Table 2) and CP uniformity (Tables 3 and 4) of the sample.

Mixer-efficiency CV decreased to 7 and 12% for Phase 1 and 2, respectively, at the longest mixing time of 330 s, and CP CV decreased to 2.0 and 3.3% for Phase 1 and Phase 2, respectively. These results indicate that the same standard value of $\leq 10\%$ used to measure mixer-efficiency CV may not be appropriate for measuring CP CV. Crude protein concentration was lower in the first bags collected and increased as the number of bags increased, indicating that the first bags contained the ingredients low in CP, such as corn. In both instances, an increased CV value for either the CP or mixer efficiency are strong indicators that other essential nutrients may not be incorporated uniformly in the mixture and, therefore, may not allow for optimal growth performance of nursery pigs. The optimal CV for CP seems to be $\leq 3\%$, whereas the standard mixer efficiency of 10% seems to be near the appropriate target value for salt.

Growth performance improved (linearly, $P < 0.5$) in both phases, with the largest response occurring when mixing time was increased from 0 to 60 s. But ADG, ADFI, and F/G improved through the 330 s mixing time in both phases and for the overall trial (d 0 to 28; Table 5). There was an improvement (linear, $P < 0.01$) in final BW with increased mixing time. Pigs fed the diet mixed for 330 s were heaviest at d 28, compared with pigs fed diets with the other mixing durations. The salt

mixer-efficiency CV for Phases 1 and 2 were 7 and 12%, which corresponds to the longest mixing time of 330 s, and the greatest growth performance seen in the trial, indicating that a CV value (≤ 10) for mixer efficiency can improve growth performance of nursery pigs.

Although the greatest improvement in growth performance was from 0 to 60 s, ADG and F/G continued to improve through 330 s mixing time. The mixer-efficiency CV values for salt for the 330-s mixing time were 7 and 12% for Phases 1 and 2, respectively; therefore, the linear ($P < 0.01$) improvement in ADG indicates that a smaller CV value is ideal for maximizing nursery pig growth performance and ensuring an adequate incorporation of all ingredients into the mixture.

Measuring CV of CP on collected samples may not be a good indicator of uniform mixing, or the ideal CV value may need to be 3% or less to indicate a uniform mixture. More research is needed to determine if CV of CP can be used as an indicator of mixing uniformity. With greater use of low-inclusion ingredients such as synthetic amino acids in swine diets, uniform mixing becomes more important to ensure that proper nutrients are supplied to the pig; these data demonstrate that inadequate feed mixing reduces nursery pig performance.

Table 1. Ingredient and Chemical Composition of Diets (As-fed Basis)^a

Item	d 0 to 14	d 14 to 28
Corn	52.25	65.36
Soybean meal (46.5% CP)	25.25	29.96
Monocalcium P (21% P)	1.00	1.60
Limestone	0.50	1.00
Fine mixing salt ^b	0.30	0.35
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
Neo-Terramycin [®] 10/10	0.70	0.70
Zinc oxide	0.25	0.00
L-threonine	0.12	0.13
L-lysine HCl	0.30	0.35
DL-methionine	0.18	0.15
Menhaden fish meal	3.75	---
Spray dried whey	15.00	---
Total	100.00	100.00
Calculated analysis		
Total lysine, %	1.45	1.35
ME, kcal/lb	1,484	1,486
Protein, %	20.36	19.49
Ca, %	0.78	0.80
P, %	0.75	0.73
Available P, %	0.48	0.41
Lysine:calorie ratio, g/Mcal	4.43	4.12

^aDietary treatments consisted of mixing the diet for 0, 30, 60, 120, or 330 s in a horizontal ribbon mixer.

^bFine mixing salt was used to aid in mixer-efficiency analysis.

Table 2. Coefficient of Variation (CV) for Various Feed Mixing Durations, %^a

Item	Mixing Time, s				
	0	30	60	120	330
d 0 to 14					
Mixer ^b	178	38	26	21	5
Bag ^c	26	20	16	11	7
d 14 to 28					
Mixer ^b	172	79	60	48	26
Bag ^d	56	45	40	33	12

^aQuantab[®] chloride titrators were used to determine CV on all samples.

^bCoefficient of variation was determined from eight samples collected from the mixer for each batch of feed.

^cThe bag CV for each mix time was determined from 12 samples (one sample collected from each bag at the bagger).

^dThe bag CV for each mix time was determined from 22 samples (one sample collected from each bag at the bagger).

Table 3. Crude Protein Analysis for Each Bag Fed, d 0 to 14^a

Bag Number	Mixing Time, s				
	0	30	60	120	330
1	8.4	14.2	18.3	19.6	21.1
2	10.1	16.9	20.0	19.9	21.7
3	17.5	22.7	21.2	20.8	21.2
4	24.1	23.9	22.6	21.2	21.3
5	25.5	24.5	20.5	22.4	21.8
6	26.0	19.9	22.4	21.4	21.6
7	24.5	23.3	21.1	20.6	21.1
8	25.3	22.2	21.3	22.3	20.3
9	26.4	22.9	21.6	21.3	21.5
10	26.0	22.5	22.0	21.6	21.4
11	24.7	23.1	23.0	20.7	21.4
12	23.5	23.4	21.9	21.3	20.8
Mean CP	21.8	21.6	21.3	21.1	21.3
STDEV	6.3	3.1	1.3	0.8	0.4
CP CV%	29.0	14.3	6.1	4.0	2.0

^aEach bag (50 lb) was analyzed for CP to evaluate variability in diet CP.

Table 4. Crude Protein Analysis for Each Bag Fed, d 14 to 28^a

Bag Number	Mixing Time, s				
	0	30	60	120	330
1	11.2	12.2	12.6	14.1	18.3
2	13.0	13.8	14.0	15.5	18.7
3	17.1	15.6	14.3	16.3	20.6
4	17.5	19.4	19.4	20.4	18.8
5	18.6	20.9	22.0	21.0	20.2
6	22.1	21.5	21.8	23.2	19.5
7	21.8	21.1	22.3	21.8	20.2
8	22.3	22.5	22.1	23.5	20.2
9	20.7	22.5	23.0	22.9	20.8
10	21.1	22.7	23.9	22.3	18.9
11	22.7	22.4	23.9	18.2	20.0
12	22.7	21.7	23.2	21.9	19.9
13	20.9	23.2	22.3	22.1	20.2
14	20.1	21.4	22.3	22.8	19.8
15	19.8	21.3	21.0	22.0	19.9
16	22.4	20.9	19.8	21.3	19.0
17	22.0	19.2	21.6	17.4	19.7
18	19.9	19.6	22.6	21.4	19.7
19	20.5	20.2	16.5	20.1	20.6
20	17.5	21.6	18.0	19.9	19.9
21	20.2	20.3	20.6	20.3	20.2
22	21.8	21.6	21.0	21.5	19.8
Mean CP	19.8	20.2	20.4	20.4	19.8
STDEV	3.0	2.9	3.3	2.6	0.7
CP CV, %	15.2	14.1	16.1	12.7	3.3

^aEach bag (50 lb) was analyzed for CP to evaluate the variability in diet CP.

Table 5. Effects of Inadequate Diet Mixing Duration on Nursery Pig Performance^{ab}

	Mixing Time, s						Probability, P <	
Item	0	30	60	120	330	SE	Linear	Quadratic
d 0 to 14								
Initial wt, lb	13.9	14.0	13.9	13.9	13.9	0.74	0.47	0.79
ADG, lb	0.42	0.55	0.54	0.56	0.62	0.05	0.001	0.40
ADFI, lb	0.56	0.66	0.61	0.64	0.69	0.04	0.02	0.82
F/G	1.64	1.22	1.14	1.14	1.12	0.15	0.02	0.11
d 14 to 28								
ADG, lb	1.04	1.24	1.26	1.31	1.42	0.10	0.001	0.25
ADFI, lb	1.51	1.81	1.75	1.85	1.96	0.12	0.01	0.24
F/G	1.55	1.47	1.40	1.42	1.38	0.7	0.04	0.26
d 0 to 28								
Final wt, lb	34.3	38.9	39.1	40.2	42.5	2.7	0.001	0.51
ADG, lb	0.73	0.89	0.90	0.94	1.02	0.08	0.001	0.18
ADFI, lb	1.04	1.23	1.18	1.25	1.33	0.08	0.01	0.27
F/G	1.55	1.40	1.32	1.33	1.30	0.07	0.01	0.07

^aA total of 180 weanling pigs (average initial BW of 13.9 ± 1.8 lb, 21 ± 3 d of age) with 6 pigs per pen and 6 pens per treatment.

^bThere were no cubic responses (P<0.05) observed.