EFFECTS OF PARTICLE SIZE AND MIXING TIME ON UNIFORMITY AND SEGREGATION IN PIG DIETS

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Summary

Diet uniformity, as represented by the coefficient of variation (CV), improved as mixing time was increased from 15 to 120 seconds and(or) corn particle size was decreased from 1,200 to 400 µm. Segregation occurred during free-fall, and the coarser particle sizes resulted in greater segregation than the finer particle sizes. Thus, reducing particle size of the cereal grain in swine diets not only improves efficiency of growth (as demonstrated in numerous KSU Swine Day Reports) but also decreases mix time needed for adequate blending and the likelihood of segregation during handling, storage, and delivery of diets to feeders.

(Key Words: Mixing, Particle Size, Diet Uniformity.)

Introduction

Mixing is an important operation in feed manufacturing. Mixing diets for broilers and nursery pigs to CVs of 10 to 20%, and diets for finishing pigs to CVs less than 50%, will increase growth performance. Obvious management/maintenance problems, such as inadequate mix time and worn mixers, will decrease mix uniformity. However, even with what is assumed to be adequate mix time and well maintained equipment, diet characteristic still are thought to have an effect on mix uniformity. Therefore, the experiments reported herein were designed to address the effects of particle size and mixing time on diet uniformity and segregation.

Procedures

To achieve desired particle size, corn was ground in a hammermill equipped with screens having openings of 1/2, 3/16, 9/64, and 1/64 inch. The corn was used in a diet formulated to .8% lysine, .6% Ca, and .5% P. All other nutrients met or exceeded NRC (1988) recommendations. Treatments were arranged as a 4× 4 factorial with corn ground to 1,200, 800, 600, and 400 µm and mix times of 15, 30, 60, and 120 seconds.

The experimental design was a split-plot with three, 100-lb batches made for each particle size treatment. A batch of each particle size was the experimental unit for the whole plot. These particle sizes (whole plot) batches then were divided for the mix time treatments.

The diets were mixed in a double-ribbon mixer. The major ingredients (corn and soybean meal) were weighed and placed in the center of the mixer and minor ingredients (monocalcium phosphate, limestone, vitamins, and minerals) were weighed (in order of decreasing percentage of the diet) and placed on top of the major ingredients. Salt (.15%) and blue (Microtracer® RF-blue) dyed particles (.01%) were added as the last ingredients on top of the diet. The mixer was stopped when a targeted mix time was reached, and 10 samples were taken at various sites throughout the mixer. The CVs were determined for each batch of feed with salt and blue particles used as markers.

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Table 1. Diet Composition[a]

Ingredients	%
Corn	73.95
Soybean meal (46.5% CP)	23.52
Monocalcium phosphate	1.06
Limestone	.92
Salt	.15
Vitamin premix	.25
Trace mineral premix	.15

[a]Formulated to .8% lysine, .6% Ca, and .5% P.

The data were analyzed as a split-plot design with polynomial regression (coefficient for unequally spaced treatments) used to characterize the shape of the response curve and to identify interactions among particle sizes and mix times. The data were analyzed as a completely randomized design.

To determine the effects of corn particle size on segregation of uniformly mixed feed, batches from the previous experiment were dumped through a 20-ft tall, 6-inch-diameter pipe into a single-hole wet/dry feeder (Crystal Spring®). Ten out of the 12 samples were taken randomly from the feeder. These samples were analyzed for salt and blue particles, and CVs were calculated.

Results and Discussion

The geometric mean particle sizes (d_{gw}) of the corn for each treatment (1,200, 825, 597, and 475 μm) were close to the targeted particle sizes of 1200, 800, 600, and 400 μm (Table 2). Uniformity of particle size (s_{gw}) decreased from 2.41 to 1.81 as d_{gw} was decreased from 1,200 to 400 μm. We have reported previously that as mean particle size was reduced, uniformity of particle size improved. Thus, fine grinding is one method of improving particle size uniformity.

The CVs for both analytical procedures (salt and blue particles) decreased dramatically (Figures 1 and 2) as mix time was increased from 15 to 30 seconds and improved little as mix time was increased further to 60 and 120 seconds (quadratic effects, $P<.001$). Also, larger corn particles yielded more variable CVs than finer corn, especially when mixing time was very short (linear effects, $P<.001$). However, a strong interaction of particle size × mix time ($P<.001$) occurred, with larger corn particle size requiring more mix time to achieve uniformity. Indeed, mix time needed for the 400 to 600 μm treatments to reach CVs of 15 to 20% or less was 15 seconds. For the 800 to 1,200 μm treatments, roughly twice as much mix time (25 to 30 seconds) was needed to reach CVs of 15 to 20% or less.

For the segregation experiment, CVs (Table 3) for both analytical procedures (salt and blue particles) increased after free fall ($P<.05$). Larger corn particle sizes caused greater segregation. However, even the 1,200 μm corn did not result in CVs that would cause concern (i.e., above 15 to 20%).

In conclusion, diet uniformity improved as mixing time was increased and corn particle size was decreased. Segregation occurred during free fall and was greater with larger particle sizes. Thus, minimizing particle size is not only important for optimizing growth performance of pigs but also for enhancing feed manufacturing processes.

Table 2. Characteristics of the Corn

	Particle Size, μm			
Item	1,200	800	600	400
Hammermill screen, in	1/2	1/4	9/64	1/16
Grain characteristics				
d_{gw}, μm[a]	1,200	825	597	475
s_{gw}, μm[a]	2.41	2.29	1.93	1.81

[a]Geometric mean particle size (d_{gw}) and log normal standard deviation (s_{gw}).

Table 3. Change in CVs for Salt and Blue Particles with Free Fall

Item	1200	800	600	400	SE
CV for salt					.45
Before	7.01	8.45	7.56	5.22	
After	12.13	9.43	8.92	8.07	
Change	5.12	.98	1.36	2.85	
CV for RF-blue					.42
Before	6.69	4.27	2.44	4.07	
After	10.99	9.02	6.93	5.29	
Change	4.30	4.75	4.49	1.22	

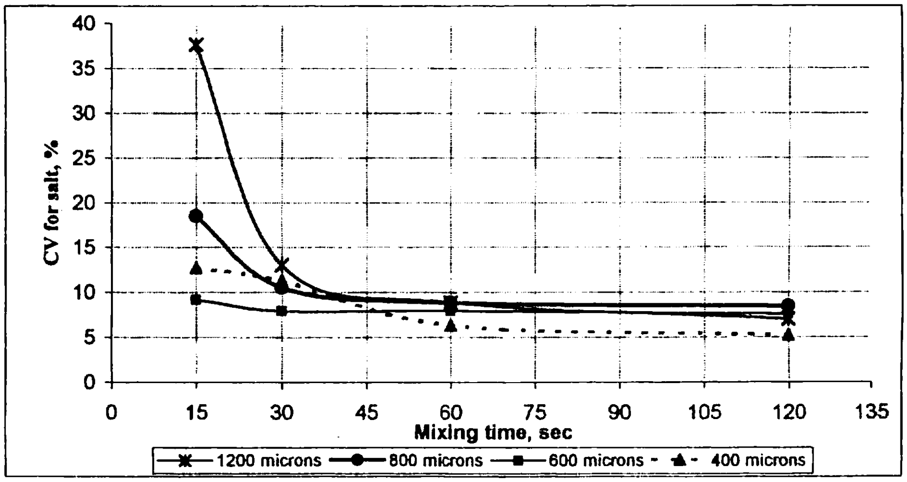

Figure 1. Effect of Particle Size and Mix Time on Diet Uniformity (Salt). Linear (P<.001) and quadratic (P<.07) effects of particle size, linear and quadratic effects of mix time (P<.001), and the particle × mix time interaction (P<.001) were observed.

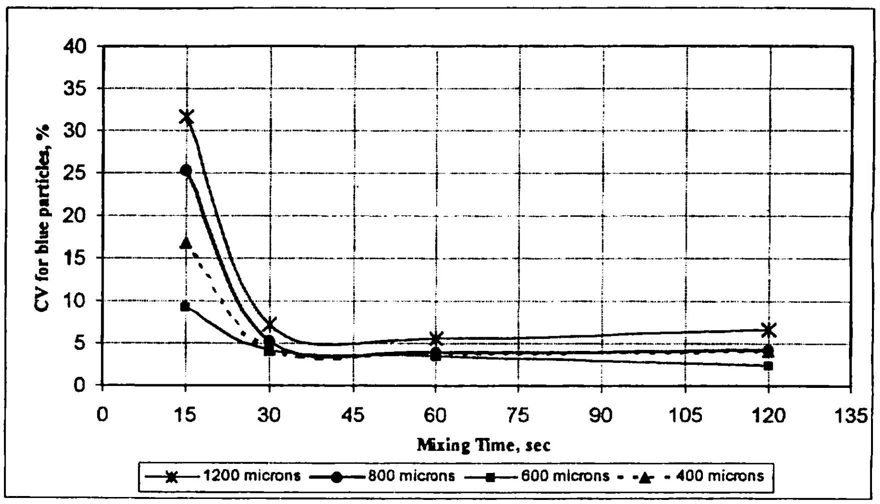

Figure 2. Effect of Particle Size and Mix Time on Diet Uniformity (Blue Particle). Linear (P<.001) and quadratic (P<.02) effects of particle size, linear and quadratic effects of mix time (P<.001), and the particle × mix time interaction (P<.001) were observed.