# Corn Particle Size Affects Nutritional Value of Simple and Complex Diets for Nursery Pigs and Broiler Chicks

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**ABSTRACT :** Two experiments were conducted to determine the effects of reducing particle size of corn from 1,000 to 500 μm in simple and complex diets for nursery pigs and broiler chicks. In Exp 1., 192 nursery pigs were used in a 24 d growth assay. Treatments were: 1) 1,000 μm corn in a simple diet; 2) 500 μm corn in a simple diet; 3) 1,000 μm corn in a complex diet; and 4) 500 μm corn in a complex diet. Overall, pigs fed complex diets had 9% greater ADG (p<0.005) and 5% greater gain/feed (p<0.01) compared to pigs fed simple diets. Also, pigs fed the 500 μm treatments had 3% better overall gain/feed than those fed the 1,000 μm treatments (p<0.007). At d 9, apparent digestibilities of DM, N and GE were greater for complex diets and diets with smaller particle size (p<0.02). At d 23, there were no differences in nutrient digestibility resulting from diet complexity, but pigs fed diets with corn ground to 500 μm had greater digestibility of DM (p<0.02) and GE (p<0.003) than pigs fed diets with corn ground to 1,000 μm. A second experiment was designed to determine if four days old broiler chicks were an acceptable model for predicting the effects of feed processing procedures on nursery pigs. Chicks fed complex diets had 3% greater gain/feed than chicks fed simple diets (p<0.001). Rate of gain and feed intake were improved by 3 and 2%, respectively, for chicks fed crumbled diets (p<0.03). However, there were several significant interactions among the main effects. For instance, crumbling did not affect gain/feed in chicks fed complex diets, but rate of gain and feed intake were increased by 7 and 6%, respectively, when simple diets were crumbled (diet complexity×diet form, p<0.001). Also, gain/feed of chicks was improved by 3% when particle size was reduced in meal diets, but not affected in chicks fed crumbles (diet form×particle size, p<0.005). Thus, our data suggested that reduction of particle size of corn was important for simple and complex diets and that a complex diet with 1,000 μm corn gave no better performance than a simple diet with 500 μm corn. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 6 : 872-877)***

**Key Words :** Nursery Pig, Broiler, Diet Complexity, Particle Size

## INTRODUCTION

Usually cereal grains are processed before incorporation into diets for pigs. This processing almost always involves grinding in a hammermill or roller mill to reduce particle size and, thus, improve nutrient digestibility (Kim et al., 2000; Hancock et al., 2000). Although ground grain improves growth performance compared to whole grain, the effects of reduced particle size on nutritional value are not the same for all cereal grains. The results of Mahan et al. (1966) and Lawrence (1983) showed increased gain/feed when the particle size of grain was reduced from coarse to fine. Wondra et al. (1995a) reported a 1.3% improvement in gain/feed of finishing pigs fed corn-based diets per 100 μm particle size reduction. Reducing mean particle size of cereal grains to <600 μm resulted in greater nutrient digestibility, rate of growth, lactation performance and decreased fecal excretion of nutrients compared to the coarser sizes of 900 to 1,000 μm (Wondra et al., 1995bc). However, these marked benefits were observed in pigs fed relatively simple diets with high proportions of cereal grain. With only 30 to 40% of a complex starter diet as cereal, the benefits of reducing particle size could, conceivably, be greatly reduced.

Thus, the experiment reported herein was designed to determine the effects of reducing particle size of corn from 1,000 to 500 μm in simple and complex diets for young pigs. Also, a chick bioassay was conducted to determine the merits of using broiler chicks as a quick and inexpensive model for the response of nursery pigs to feed processing technologies.

## MATERIALS AND METHODS

### Experiment 1

A total of 192 nursery pigs (initial BW of 5.3 kg and 21 d of age) were used in a 24 d growth assay. The pigs were blocked by weight and allotted (based on sex and ancestry) with eight pigs per pen and six pens per treatment. Treatments were: 1) 1,000 μm corn in a simple diet; 2) 500 μm corn in a simple diet; 3) 1,000 μm corn in a complex diet; and 4) 500 μm corn in a complex diet. The corn was ground in a hammermill through screens with openings of 12.7 and 1.6 mm to yield the 1,000 and 500 μm particle size treatments. Particle size, particle size uniformity and surface area of the grains were determined with 100 g aliquots of the pooled sample (ASAE, 1983).

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The simple diet regimen was corn-soybean meal-whey-based for d 0 to 10 and 10 to 24 (table 1). The complex diet regimen was based on dried whey, lactose, spray-dried porcine plasma protein, spray-dried vital wheat gluten and spray-dried blood meal for d 0 to 10 and dried whey and spray-dried blood meal for d 10 to 24. All diets contained 1.60% lysine, 0.45% methionine, 0.90% Ca and 0.80% P for d 0 to 10, and 1.30% lysine, 0.36% methionine, 0.80% Ca and 0.70% P for d 10 to 24. All diets were provided with all other nutrients in excess of the levels recommended by NRC (1998). The diets were fed in pelleted form. Pellet durability was determined 30 min after pelleting with 500 g of cold pellets (ASAE, 1987).

The pigs were housed in an environmentally controlled nursery room. The temperature was maintained at 34°C during wk 1 and decreased 1.5°C each week thereafter. Each pen (1.2 m×1.5 m with woven-wire flooring) had a self-feeder and nipple water to allow *ad libitum* consumption of feed and water. Pigs and feeders were weighed on d 0, 10 and 24 to calculate of ADG, ADFI and gain/feed. Chromic oxide (0.15%) was included in the diets as an indigestible marker and on d 9 and 23, fecal samples were collected from four pigs per pen by rectal massage. The fecal samples were dried and pooled within pen on an equal weight basis. Concentrations of Cr (Williams et al., 1962), DM and N (AOAC, 1990) and GE (1241EA Adia Calorimeter, Parr Inst. Co., Moline, IL 61265, USA) in the feces and diets were determined to allow calculation of apparent digestibilities of DM, N and GE using the indirect ratio method.

The data were analyzed as a randomized complete block design (initial weight as the blocking criterion) with pen as the experimental unit. Pigs were blocked on the basis of initial weight. Analysis of variance was performed using the GLM procedure of SAS (1988). Treatment comparisons were made with the contrasts: 1) simple vs complex diet formulation; 2) 1,000 vs 500 μm mean particle size; and 3) the simple vs complex×1,000 vs 500 μm treatment interaction.

**Table 1.** Diet composition for the pig experiment (as-fed basis), %

| | D 0 to 10[a] | | D 10 to 24[b] | |
|---|---|---|---|---|
| | Simple | Complex | Simple | Complex |
| Ingredient | | | | |
| Corn | 40.25 | 25.26 | 56.72 | 45.35 |
| Soybean meal (46.5% CP) | 21.93 | 23.84 | 31.68 | 24.58 |
| Dried whey | 20.00 | 20.00 | 5.00 | 20.00 |
| Lactose | - | 10.00 | - | - |
| Soy isolate | 10.00 | - | - | - |
| Spray-dried plasma protein | - | 4.00 | - | - |
| Spray-dried wheat gluten | - | 4.00 | - | - |
| Spray-dried blood meal | - | 2.00 | - | 2.00 |
| Soybean oil | 3.00 | 6.00 | 2.00 | 4.00 |
| Lysine-HCl | 0.15 | 0.20 | 0.20 | 0.10 |
| DL-methionine | 0.07 | 0.08 | 0.04 | 0.07 |
| Monocalcium phosphate | 1.52 | 1.91 | 1.42 | 1.22 |
| Limestone | 0.83 | 0.61 | 0.84 | 0.68 |
| Salt | 0.30 | 0.15 | 0.40 | 0.30 |
| Vitamin premix[c] | 0.25 | 0.25 | 0.25 | 0.25 |
| Trace mineral premix[d] | 0.20 | 0.20 | 0.20 | 0.20 |
| Zinc oxide | 0.35 | 0.35 | - | - |
| Copper sulfate | - | - | 0.10 | 0.10 |
| Antibiotic[e] | 1.00 | 1.00 | 1.00 | 1.00 |
| Chromic oxide[f] | 0.15 | 0.15 | 0.15 | 0.15 |

[a] Diets for d 0 to 10 were formulated to contain 1.60% lysine, 0.45% methionine, 0.90% Ca and 0.80% P.

[b] Diets for d 10 to 24 were formulated to contain 1.30% lysine, 0.36% methionine, 0.80% Ca and 0.70% P.

[c] Provided the following per kilogram of the complete diet: 11,025 IU of vitamin A; 1,103 IU of vitamin $D_3$; 44 IU of vitamin E; 4.4 mg of vitamin K (menadione bisulfate complex); 8.3 mg of riboflavin; 50 mg of niacin; 29 mg of d-pantothenic acid (as d-calcium pantothenate); 166 mg of choline; and 33 μg of vitamin $B_{12}$.

[d] Provided the following per kilogram of the complete diet: 53 mg of Mn; 220 mg of Fe; 220 mg of Zn; 22 mg of Cu; 0.4 mg of I; and 0.4 mg of Se.

[e] Provided 150 g/ton of apramycin in diets for d 0 to 10 and 50 g/ton of carbadox in diets for d 10 to 24.

[f] Used as an indigestible marker.

**Experiment 2**

Four hundred and eighty broiler chicks (4 d old and 94 g average BW) were used to determine the effects of simple (cereal grain-soybean meal-based) vs complex (cereal grain-soybean meal-based with 6% tallow, 4% meat and bone meal and 1% feather meal) diet formulation, diet form (meal vs crumble) and corn particle size (1,000 vs 500 μm) in a 2×2×2 factorial arrangement of treatments. The diets were formulated to contain 1.32% lysine, 0.61% methionine, 1.10% Ca and 0.50% available P (table 2) and met or exceeded the nutrient concentrations recommended by the NRC (1994). The chicks were allotted by weight to 0.33 m×0.99 m cage (five chicks per cage and 12 cages per treatment) in battery brooders and given *ad libitum* access to feed and water during the 14 d experiment. Data were collected at the beginning and end of the experiment to determine ADG, ADFI and gain/feed. At the end of the experiment, the chicks were killed by cervical dislocation to collect of gizzards.

The data for growth performance were analyzed as a

**Table 2.** Diet composition for the chicks experiment (as-fed basis), %[a]

| Ingredient | Simple | Complex |
|---|---|---|
| Corn | 54.94 | 48.28 |
| Soybean meal (46.5% CP) | 39.30 | 35.90 |
| Meat and bone meal | - | 4.00 |
| Feather meal | - | 1.00 |
| Tallow | 1.00 | 6.00 |
| DL-methionine | 0.30 | 0.30 |
| Dicalcium phosphate | 2.02 | 2.05 |
| Limestone | 1.14 | 1.17 |
| Salt | 0.40 | 0.40 |
| Vitamin and mineral premixes[b] | 0.50 | 0.50 |
| Vitamin add pack[c] | 0.25 | 0.25 |
| Copper sulfate | 0.05 | 0.05 |
| Antibiotic[d] | 0.10 | 0.10 |

[a] Diets were formulated to 1.32% lysine, 0.61% methionine, 1.10% Ca and 0.50% available P.

[b] Provided the following per kilogram of the complete diet: 5,512 IU of vitamin A; 551 IU of vitamin $D_3$; 22 IU of vitamin E; 2.2 mg of vitamin K (menadione bisulfate complex); 5.5 mg of riboflavin; 30.3 mg of niacin; 13.8 mg of d-pantothenic acid (as d-calcium pantothenate); 551 mg of choline; 0.03 mg of vitamin $B_{12}$; 100 mg of Mn; 100 mg of Fe; 100 mg of Zn; 10 mg of Cu; 3 mg of I; 0.3 mg of Se and 1.0 mg of Co.

[c] Provided the following per kilogram of the complete diet: 154 mg of choline; 132 mg of biotin and 660 mg of folic acid.

[d] Provided 110 mg of chlortetracycline per kilogram of the complete diet.

randomized complete block design with a 2×2×2 factorial arrangement of treatments using the GLM procedure of the SAS (1988). Weight block and treatment were defined sources of variation and pen was the experimental unit. For analyses of gizzard weight, final body weight was used as a covariate.

## RESULTS AND DISCUSSION

### Experiment 1

For the pig experiment, particle sizes of the ground corn were close to those desired (table 3). As geometric mean particle size was decreased, log normal standard deviation of particle size decreased (from 2.4 to 1.9) and surface area of the ground corn increased (from 70.7 to 97.2 $cm^2/g$). Pellet durabilities were similar among all treatments (i.e., PDI values of 97.7 to 99.1%). Reducing particle size of the cereals is thought to provide greater surface area for steam conditioning (MacBain, 1966), which in turn improves pellet durability (Skoch et al., 1983). However, with all of our diets above 97% PDI (very high by industry standards) it was not surprising that reducing particle size had little effect on pellet quality. Thus, our data agree with reports by Young (1962) and Martin (1984) that, from a pellet quality standpoint, there is little advantage to reducing particle size below 900 μm.

**Table 3.** Characteristics of corn and diets for the pig experiment

| | Simple | | Complex | |
|---|---|---|---|---|
| | 1,000 | 500 | 1,000 | 500 |
| Grain characteristics | | | | |
| Geometric mean particle size, μm | 938 | 565 | -[a] | - |
| Standard deviation of the particle size | 2.4 | 1.9 | - | - |
| Surface area, $cm^2/g$ | 70.7 | 97.2 | - | - |
| Diet characteristics | | | | |
| Pellet durability index | | | | |
| D 0 to 10 | 98.9 | 99.1 | 98.8 | 98.9 |
| D 10 to 24 | 97.7 | 98.4 | 98.8 | 98.8 |

[a] The same corn was used for simple and complex diets.

For d 0 to 10, pigs fed complex diets had 10% greater ADG ($p<0.04$) than pigs fed simple diets (table 4). Pigs of the 500 μm treatments tended to have greater ADG than those of the 1,000 μm treatments ($p<0.06$), but there were no differences in gain/feed ($p>0.11$). Overall, pigs fed complex diets had 9% greater ADG ($p<0.005$) and 5% greater gain/feed ($p<0.01$) than pigs fed simple diets. Also, pigs of the 500 μm treatments had 3% better overall gain/feed than those of the 1,000 μm treatments ($p<0.007$). It was anticipated when this experiment was designed that the response to the reduction of particle size might be greater in simple diets (with their greater proportion as cereal grain) than in complex diets. Hedde et al. (1985) reported greater ADG for growing-finishing pigs fed diets with finely ground corn than for coarsely ground corn. Furthermore, fine grinding was reported to improve gain/feed in starter pigs fed corn (Wu, 1985), sorghum (Ohh et al., 1983) and barley (Goodband and Hines, 1988).

In the overall data, ADG of pigs fed simple diets was improved more than ADG of pigs fed complex diets as particle size was reduced from 1,000 to 500 μm. However, the improvements in gain/feed with decreased particle size were similar in simple and complex diets. Finally, the ADG and gain/feed values for pigs fed simple diets with corn ground to 500 μm were essentially the same as those for pigs fed complex diets with corn ground to 1,000 μm. Thus, the added cost of complex diet formulations is wasted if proper attention is not given to particle size of the cereal grain in the diet.

At d 9, apparent digestibilities of DM, N and GE were higher for complex diets and diets with smaller particle size ($p<0.01$). At d 23, there were no differences in nutrient digestibility resulting from diet complexity, but pigs fed diets with corn ground to 500 μm had greater digestibility of DM ($p<0.02$) and GE ($p<0.003$) than pigs fed diets with corn ground to 1,000 μm. Owsley et al. (1981) reported that reduction in particle size of sorghum from 1,262 to 802 to 471

**Table 4.** Growth performance of weanling pigs fed simple and complex diets with corn milled to 1,000 and 500 μm[a]

| | Simple | | Complex | | SE | Contrasts[b] | | |
|---|---|---|---|---|---|---|---|---|
| | 1,000 | 500 | 1,000 | 500 | | 1 | 2 | 3 |
| D 0 to 10 | | | | | | | | |
| ADG, g | 275 | 317 | 321 | 328 | 12 | 0.04 | 0.06 | NS[c] |
| ADFI, g | 291 | 325 | 349 | 332 | 10 | 0.006 | NS | 0.02 |
| Gain/feed, g/kg | 945 | 975 | 920 | 988 | 28 | NS | NS | NS |
| D 10 to 24 | | | | | | | | |
| ADG, g | 483 | 519 | 535 | 533 | 11 | 0.01 | NS | NS |
| ADFI, g | 692 | 717 | 728 | 713 | 19 | NS | NS | NS |
| Gain/feed, g/kg | 698 | 724 | 735 | 748 | 10 | 0.006 | 0.09 | NS |
| D 0 to 24 | | | | | | | | |
| ADG, g | 395 | 426 | 445 | 448 | 10 | 0.005 | 0.04 | 0.07 |
| ADFI, g | 527 | 554 | 570 | 553 | 14 | NS | NS | NS |
| Gain/feed, g/kg | 750 | 769 | 781 | 810 | 9 | 0.01 | 0.007 | NS |
| Apparent digestibility, % | | | | | | | | |
| D 9 | | | | | | | | |
| DM | 85.2 | 87.3 | 86.7 | 88.6 | 1.3 | 0.01 | 0.001 | NS |
| N | 80.2 | 83.7 | 84.1 | 84.9 | 2.4 | 0.01 | 0.02 | NS |
| GE | 85.0 | 87.1 | 86.7 | 88.4 | 1.4 | 0.01 | 0.001 | NS |
| D 23 | | | | | | | | |
| DM | 87.4 | 88.0 | 87.9 | 88.8 | 0.8 | 0.06 | 0.02 | NS |
| N | 83.8 | 84.8 | 84.5 | 84.6 | 1.5 | NS | NS | NS |
| GE | 88.1 | 89.0 | 88.1 | 89.5 | 0.9 | NS | 0.003 | NS |

[a] One hundred ninety-two weanling pigs (average initial BW 5.3 kg and 21 d of age, with eight pigs per pen and six pens per treatment) were used.

[b] Contrasts were: 1=simple vs complex diet formulation; 2=1,000 vs 500 μm particle size; and 3=simple vs complex×1,000 vs 500 μm.

[c] NS=Not significant (p>0.10).

μm improved the apparent digestibilities of DM, starch, N and GE measured at the terminal ileum and for the total digestive tract of growing pigs. Giesemann et al. (1990) observed improvements in digestibilities of DM, N and GE of corn-based diets fed to growing-finishing pigs as particle size of cereal was reduced from 1,506 to 641 μm. Particle size reduction of cereal grains is though to improve digestibility and gain/feed because the greater surface area created allows for increased contact with digestive enzymes (Kim et al., 2000; Hancock et al., 2000).

In conclusion, our data suggest that reducing particle size of corn is important for simple and complex diets when fed to nursery pigs. Also, complex diets with 1,000 μm corn give no better performance than a simple diets with 500 μm corn.

**Experiment 2**

For the chicks experiment (table 5), there were no 3-way interactions among diet complexity, diet form and particle size (p>0.2). Chicks fed complex diets had 3% greater gain/feed than chicks fed simple diets (p<0.001) which might have resulted from the higher energy content of the complex diets. Rate of gain and feed intake were improved by 3 and 2%, respectively, for chicks fed crumbled diets vs chicks fed meal diets (p<0.03). However, there were 2-way interactions for several response criteria. Reducing particle size of corn from 1,000 to 500 μm increased rate of gain by 4% and feed intake by 2% in complex diets, but had little effect on rate of gain or feed intake in chicks fed simple diets (particle size×diet complexity, p<0.02). This response was not consistent with the particle size×diet complexity effect in nursery pigs (i.e., a trend for greater response to decreased particle size in simple diets).

Crumbling did not affect gain/feed in chicks fed complex diets; however rate of gain and feed intake were increased by 7 and 6%, respectively, when simple diets were crumbled (diet form×diet density interaction, p<0.001). This is in agreement with Hussor and Robblee (1962) and Reece et al. (1984, 1985) who reported that feeding simple corn-soybean meal-based diets as crumbles vs mash increased rate of gain in broiler as compared with mash diets. Gain/feed was improved by 3% when particle size was reduced in meal diets but not affected in chicks fed crumbles (particle size×diet form interaction, p<0.005). Thus, there were noteworthy differences among nursery pigs and broiler chicks for response to diet complexity and particle size, and caution should be used when extrapolating results from chick assays to nursery pigs.

**Table 5.** Effects of diet complexity, physical form, and particle size on performance of broiler chicks[a]

| | Simple | | | | Complex | | | | SE |
|---|---|---|---|---|---|---|---|---|---|
| | Meal | | Crumble | | Meal | | Crumble | | |
| | 1,000 | 500 | 1,000 | 500 | 1,000 | 500 | 1,000 | 500 | |
| Weight gain, g/d | 34.1 | 34.2 | 37.0 | 35.9 | 35.2 | 36.9 | 35.3 | 36.2 | 0.2 |
| Feed intake, g/d | 48.6 | 46.8 | 50.9 | 50.0 | 48.3 | 49.6 | 47.1 | 48.7 | 0.3 |
| Gain/feed, g/g | 0.702 | 0.731 | 0.727 | 0.718 | 0.729 | 0.744 | 0.750 | 0.743 | 0.003 |
| Gizzard weight, g | 18.2 | 16.8 | 20.3 | 17.0 | 19.7 | 16.7 | 18.3 | 18.6 | 0.4 |
| Contrast[b] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | |
| Weight gain | NS[c] | 0.007 | NS | NS | 0.02 | 0.001 | NS | | |
| Feed intake | NS | 0.03 | NS | NS | 0.001 | 0.001 | NS | | |
| Gain/feed | 0.001 | 0.09 | NS | 0.005 | NS | NS | NS | | |
| Gizzard weight | NS | NS | NS | 0.01 | 0.08 | NS | NS | | |

[a] A total of 480 broiler chicks (average initial BW 94 g, with five birds per cage and 12 cages per treatment) were used in a 14 d growth assay.

[b] Contrasts were: 1) simple vs complex; 2) meal vs crumble; 3) 1,000 vs 500 μm; 4) form×particle size; 5) complexity×particle size; 6) complexity×form; and 7) complexity×form×particle size.

[c] NS=Not significant (p>0.10).

Healy et al. (1994) and Nir et al. (1994) indicated that improved feed utilization with reduced particle size is possibly related to the effects of particle size on the digestive tract. They reported that feeding diets with coarse ground grains to broiler chicks increased the gizzard weights. In the present experiment, gizzard weights were both influenced by particle size and form of the diet. Gizzard weights were reduced when birds were fed the diets with 500 μm corn in meal form, but not affected by particle size of corn in the crumbled diets (particle size×diet form interaction, p<0.01).

In conclusion, from the results of the chicks experiment, the nutritional value of simple diets is increased by crumblizing and particle size reduction; however, in complex diets fed as crumbles, reducing particle size does not improve growth performance of broiler chicks.

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Table 5. Effects of diet complexity, physical form, and particle size on performance of broiler chicks[a]

[a] A total of 480 broiler chicks (average initial BW 94 g, with five birds per cage and 12 cages per treatment) were used in a 14-d growth assay.

[b] Contrasts were:1) simple vs complex; 2) meal vs crumble; 3) 1,000 vs 500 μm; 4) form × particle size; 5) complexity ×

particle size; 6) complexity × form; and 7) complexity × form × particle size.
[c] NS = not significant ($P>0.10$).