FARMING

Effects of Diet Particle Size on Poultry Performance

► Adjusting particle size tremendously affects feed cost, nutrient digestibility, animal welfare, and overall profitability of poultry operations. The target particle size in poultry diets depends on the phase of production. Starter diets should contain a small percentage of coarse particles of corn, which should then gradually increase with body weight and age. Following these strategies is shown to improve bird performance, reduce feed cost, and positively impact overall profitability.

Feed costs represent between 60 and 70 percent of production costs in poultry diets. Therefore, poultry producers are challenged to find cost-effective nutritional and processing strategies to remain profitable. The majority of feed ingredients used in poultry feeds require some type of grinding. Cereal grains such as corn and wheat are ground at the feed mill while other ingredients are received in a ground form.

Grinding is the first stage in feed manufacturing followed by batching and mixing. Particle size reduction during grinding increases the surface area of feed ingredients, which increases their interaction with digestive enzymes, improves mixing characteristics, and reduces nutrient segregation during handling, particularly in mash diets. However, as the target particle size decreases, grinding cost increases, and throughput (ton/hour) decreases. In addition, fine grinding can lead to moisture losses and flowability problems at the feed mill and at farm silos. In poultry diets, excessively ground ingredients have been associated with a higher gastrointestinal passage rate, poor gut health, and low nutrient digestibility.

Unlike mammals, birds have small intestinal volume, which is advantageous as the energetic costs of flying increase with the load carried. Birds' gizzard, or grinding organ, compensates for their shorter gastrointestinal tract. A well-developed gizzard improves gut motility, increases the retention time of the feed in the gastrointestinal tract, promotes better digestion and absorption of nutrients in the upper gut, and reduces the risks of coccidiosis and other enteric diseases in the lower gut.

Incorporating coarse particles in birds' diets may also increase nutrient digestibility and reduce microbial contamination either by increasing the number of beneficial bacteria or reducing pathogenic bacteria. Coarse particles increase the gastric reverse peristalsis between the gizzard and proventriculus, increasing the secretion of hydrochloric acid by the proventriculus and reducing the pH of the gizzard, which may inactivate pathogenic bacteria such as *Salmonella* and *Clostridium perfringens* before entering the small intestine.

In addition, feeding whole grains or coarsely ground ingredients reduces proventricular swelling. Research supports using whole corn at 0, 3, 6, and 9 percent in broiler diets. Broilers reared from 14 to 42 days of age can be fed up to 9 percent whole corn inclusion without adversely affecting performance or carcass characteristics. Grinding is expensive; however, establishing an optimum inclusion of whole corn can save time, energy, and money during feed manufacturing.

In another study, two levels of coarse corn at 0 and 50 percent were tested during the grower and finisher periods. The inclusion level of coarse corn was obtained by replacing 0 or 50 percent of the total dietary corn with coarse corn (1,359 μm) in a basal diet that contained fine corn (294 μm). As 50 percent coarse corn replaced fine corn, the average particle size of the mash diet before pelleting increased from 432 to 640 μm in the grower diets and from 389 to 651 μm in the finisher diets and produced a bimodal particle size distribution. In this study, pellets were screened to remove the variability caused by pellet fines on growth performance.

Table 1. Effect of Dietary Coarse Corn Inclusion on Performance, Organ Development, Litter Condition, and Nutrient Digestibility at 49 Days of Age[a]

	Coarse Corn Inclusion (%)		
Item	**0**	**50**	**SEM**
Dietary Particle Size (µm)	415	630	
Performance			
Feed Intake (g)	7328	7228	55
Body weight (g)	3860	3899	23
FCR (g:g)	1.92^{A}	1.88^{B}	0.01
Organ Development			
Gizzard (mg/g BW)	8.11^{B}	9.21^{A}	0.07
Proventriculus (mg/g BW)	2.38^{A}	2.27^{B}	0.20
Gizzard/Proventiculus	3.46^{B}	4.13^{A}	0.17
Litter condition			
Nitrogen	3.78^{A}	3.46^{B}	0.04
Moisture (%)	35.87	38.53	1.07
pH	8.36^{B}	8.45^{A}	0.03
Nutrient digestibility			
Nitrogen	74.02^{B}	76.60^{A}	0.77
Energy	61.88^{B}	66.07^{A}	0.89

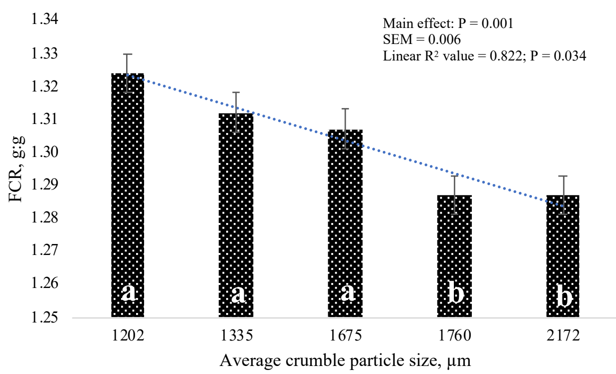
[a] Adapted from Xu et al. (2015). Data represents means of chicks fed diets containing either 0 or 50% coarse corn.

[A, B] Means in the same row with different subscripts differ ($P < 0.01$)

The addition of 50 percent coarse corn significantly improved feed efficiency during the grower and finisher periods as shown in table 1. The improvement in feed efficiency when 50 percent coarse corn replaced fine corn appeared to be associated with higher nitrogen and energy digestibility. The addition of coarse corn also affected the nitrogen, moisture, and pH of litter. Nitrogen decreased by 8.47 percent when 50 percent coarse corn replaced the fine corn. Reducing nitrogen in the litter is essential for reducing footpad dermatitis, particularly in conditions of high litter moisture.

Several studies reported improved nutrient digestibility when birds were fed coarse particles. Researchers studied the interactions between feed form (mash, 3- and 4-millimeter pelleted diets) and corn particle size (750, 1,150, and 1,550 µm) on nutrient digestibility of broilers reared from 1 to 39 days of age. Apparent ileal digestibility (AID) of protein, energy, and fat of broilers fed mash or 4-millimeter pelleted diets were not influenced by corn particle size. However, AID of protein and energy increased 7.6 and 6.4 percent as corn particle size increased from 750 to 1,550 µm in 3-millimeter pellets, respectively. Broiler nutrient digestibility was improved with pelleted feed, and optimum corn particle size in broiler diets depends on the feed form.

The particle size of soybean meal (SBM) can also influence broiler performance. One study reported an improved mineral digestibility when the particle size of SBM increased from 891 to 1,239 µm. In contrast, precaecal amino acid digestibility was improved by including finely ground SBM. The effect of SBM source (solvent extracted and expeller extracted) and particle size (coarse-1,330 µm and fine-520 µm) on broiler performance was studied from 1 to 49 days of age. Higher body weight and improved feed efficiency at 35 and 49 days of age occurred when birds were fed coarse SBM. There was an interaction between SBM source and particle size on BW at 49 days of age. No differences in BW were observed when birds were fed solvent-extracted and expeller-extracted SBM in a coarse ground form. However, grinding the expeller-extracted SBM depressed BW at 49 days of age.



[A] Adapted from Lemons et al. (2019)
[a,b] Means in the same row with different subscripts differ (P < 0.05)

Figure 1. Experiment 1 comparisons of Ross x Ross 708 male broiler performance when fed starter diets varying in average feed particle size from day 0 to 14A.

Another experiment was conducted to evaluate the effect of SBM particle size (530 and 1,300 µm) and trypsin inhibitor levels of expeller-extracted SBM on the growth performance of chicks from 1 to 14 days of age. This study showed that increasing the particle size of expeller-extracted SBM improved growth performance, especially when the trypsin inhibitor level was greater than 9 TIU per milligram. It appears that coarse grinding expeller-extracted SBM increases gastric reverse peristalsis (gizzard and proventriculus) and causes acid denaturation of trypsin inhibitors, increases bile movement into the gizzard, releases trypsin inhibitors more slowly or consistently, and consequently allows chicks to adapt.

Although there are multiple benefits of feeding coarse particles, the age and size of the birds are important when deciding on particle size. Newly hatched chicks can have problems consuming whole grains or coarse particles, an issue directly influenced by beak size.

One study reported a significant decrease in BW gain at 7 and 15 days of age when the particle size of corn in diets fed to poults increased from 606 to 1,094 µm. Chicks fed whole wheat had lower BW due to reduced feed consumption compared to chicks receiving ground wheat. There was also a linear decrease in BW gain from 0 to 21 days and reduced feed efficiency from 0 to 7 days when the particle size of corn increased from 557 to 1,387 µm, suggesting that young chicks might have difficulty swallowing whole grains.

The particle size of crumbles can also influence broiler performance (figure 1). In one study, broilers were fed crumbles of varying particle size during the starter phase (0 to 14 days), and performance increased when the particle size of crumbles increased. The average particle size of the crumbles was 1,202, 1,335, 1,675, 1,760, and 2,172 µm and 1,174, 1,423, 1,883, 2,049, 2,257, 2,800, 3,456, and 3,736 µm for the first and second experiment, respectively. Broilers fed a crumbled diet with an average particle size of 1,760 or 2,172 µm had a better feed conversion ratio (FCR) compared to broilers fed 1,202, 1,335, and 1,675 µm. There was also a linear relationship between crumble particle size and FCR. Recommended crumble particle size is around 2,800 µm to maximize BW and FCR during the starter phase.

Much research supports including more finely ground particle sizes during the starter phase. Four dietary treatments evaluated SBM particle size (coarse 1,290 µm and fine 470 µm) and corn particle size (coarse 1,330 µm and fine 520 µm) in a factorial arrangement (table 2). Chicks were fed a starter diet in mash form from 1 to 19 days of age. Chicks fed fine SBM had a greater BW at 19 days of age than chicks fed coarse SBM, primarily driven by higher feed consumption.

Table 2. Effect of SBM and Corn Particle Size on Performance of Broilers from 1 to 19 Days of Age[*]

Particle Size (µm)		Body Weight (g)		Feed Intake (g)		FCR (g:g)	
SBM	*Corn*	7 d	19 d	1-7 d	1-19 d	1-7 d	1-19 d
1290		157^{B}	774^{b}	130^{B}	906^{b}	1.17^{A}	1.25
470		177^{A}	809^{a}	141^{A}	945^{a}	1.07^{B}	1.24
SEM		2	12	2	10	0.02	0.01
	1330	154^{B}	755^{B}	130^{B}	900^{B}	1.20^{A}	1.27^{A}
	520	180^{A}	829^{A}	141^{A}	951^{A}	1.04^{B}	1.22^{B}
	SEM	2	12	2	10	0.02	0.01
Source of variation		*P-value*					
SBM particle size		0.001	0.043	0.001	0.011	0.004	0.507
Corn particle size		0.001	0.001	0.001	0.001	0.001	0.002

[*] Adapted from Pacheco et al. (2013).

[A,B] Means in the same row with different subscripts differ (P < 0.01)
[a, b] Means in the same row with different subscripts differ (P < 0.05)

Furthermore, chicks fed fine corn had greater BW at 7 and 19 days of age, influenced by both greater feed consumption and improved feed efficiency. In this study, grinding corn from 1,290 to 470 µm improved feed efficiency by 15 and 4 percent at 7 and 19 days of age, respectively. Including whole grain or coarse ingredients can reduce BW and feed efficiency, particularly during the starter period, likely because the gizzard of a newly hatched chick is not fully developed and is unable to grind large particles as efficiently as older birds do. Further, the grinding process in the gizzard requires energy that is diverted from growth. For these reasons, consider incorporating large quantities of coarse materials only in later production phases.

Another study evaluated including mash in diets of ground corn with different particle size, fine (781 ± 2.09 µm), small (950 ± 2.08 µm), medium (1,042 ± 2.13 µm), large (1,109 ± 2.22 µm), and coarse (2,242 ± 2.11 µm), on 3- to 6-week-old broiler performance and nutrient retention. Feed intake and feed efficiency decreased as particle size increased.

It has also been reported that different corn particle sizes in a late-rearing-phase diet can affect feed intake and FCR. Broiler chickens were fed finisher diets with corn particle sizes of 615, 863, 1,644, and 2,613 µm from 28 to 42 days of age. Feed intake increased by approximately 180 grams on broilers fed diets containing a corn particle size of 1,644 µm compared to the broilers fed diets with a corn particle size of 615 µm. The broilers fed corn particle sizes of 1,644 and 2,613 µm had a higher FCR at 42 days compared with the birds fed diets with corn particle sizes of 615 and 863 µm.

In conclusion, particle size manipulation has a tremendous effect on feed cost, nutrient digestibility, animal welfare, and the overall profitability of poultry operations. The target particle size in poultry diets should depend on the phase of production. Starter diets should contain a small percentage of coarse particles of corn, which should then gradually increase with BW and age.

It is recommended that sampling be conducted and particle size analyzed at least weekly after any preventive or corrective maintenance is performed. Maintenance includes changing screens or hammers or changing rotation as well as corrections when the characteristics of corn change, such as new crop corn. Following these strategies is shown to improve bird performance, reduce feed cost, and positively impact overall profitability.

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Wilmer Pacheco, *Extension Specialist*, Assistant Professor; **Joseph Gulizia**, Student Assistant, and **Isaac Vargas**, Student Assistant, all in Poultry Science, Auburn University

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