

## Effects of Different Corn Grinding Particle Sizes on Production Performance, Egg Quality, and Digestive Function in Laying Hens (Postprint)

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### Abstract

This experiment aimed to investigate the effects of different corn grinding particle sizes on the production performance, egg quality, and digestive function of laying hens under the same dietary formula conditions. Feed ingredients were ground using a hammer mill, with corn ground through screen apertures of 4.0, 5.0, 6.0, 7.0, 8.0, and 10.0 mm, while other feed ingredients were all ground through a 5.0 mm screen aperture. A total of 2,592 Hy-Line Brown laying hens at 210 days of age were selected and randomly divided into 6 groups with 6 replicates per group and 72 hens per replicate, with each group fed diets containing corn ground to different particle sizes. The experimental period lasted for 16 weeks. The results showed that: 1) The geometric mean particle size of corn and the complete diet increased with increasing screen aperture diameter, although the difference in the complete diet was relatively small. As the screen aperture diameter gradually increased, grinding energy consumption progressively decreased from 3.93 kWh/t to 1.19 kWh/t. 2) As corn grinding particle size increased, average egg weight exhibited a trend of first increasing then decreasing, with the 5.0 mm screen aperture group being significantly higher than the 10.0 mm screen aperture group ( $P < 0.05$ ). As corn grinding particle size increased, broken egg rate and soft egg rate showed a trend of first decreasing then increasing, with the 6.0 mm screen aperture group having a significantly lower broken egg rate than the 10.0 mm screen aperture group ( $P < 0.05$ ), and the 7.0 mm screen aperture group having a significantly lower soft egg rate than the 4.0 mm screen aperture group ( $P < 0.05$ ). 3) The yolk ratio in the 7.0 mm screen aperture group was significantly greater than that in the 5.0 mm screen aperture group ( $P < 0.05$ ). 4) The apparent digestibility of crude protein in the 5.0 mm screen aperture group was significantly higher than that in the 6.0, 7.0, 8.0, and 10.0 mm screen aperture groups ( $P < 0.05$ ), the apparent digestibility of gross energy in the 5.0 mm screen aperture group was significantly higher than that in the 4.0, 7.0, and 10.0 mm screen aperture groups ( $P < 0.05$ ), and

the apparent digestibility of dry matter in the 7.0 mm screen aperture group was significantly higher than that in the 4.0 and 10.0 mm screen aperture groups ( $P < 0.05$ ). 5) The number of cecal *Escherichia coli* in the 7.0 mm screen aperture group was significantly lower than that in the 4.0 and 10.0 mm screen aperture groups ( $P < 0.05$ ), the jejunum index in the 5.0 mm screen aperture group was significantly higher than that in the 6.0, 7.0, and 8.0 mm screen aperture groups ( $P < 0.05$ ), the pH of proventriculus chyme in the 8.0 mm screen aperture group was significantly lower than that in the 4.0 and 5.0 mm screen aperture groups ( $P < 0.05$ ), and the pH of ileum chyme in the 6.0 mm screen aperture group was significantly higher than that in the 4.0, 5.0, 7.0, and 10.0 mm screen aperture groups ( $P < 0.05$ ). In conclusion, for laying hen diets, a corn grinding screen aperture diameter of 6.0 mm resulted in better production performance and egg quality, and was beneficial for intestinal health.

## Full Text

### Effects of Different Grinding Particle Sizes of Corn on Performance, Egg Quality and Digestive Function of Laying Hens

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## Abstract

This experiment was conducted to investigate the effects of different corn grinding particle sizes on the performance, egg quality, and digestive function of laying hens under identical dietary formulation conditions. Feed ingredients were ground using a hammer mill, with corn ground through sieve diameters of 4.0, 5.0, 6.0, 7.0, 8.0, and 10.0 mm, while other feed ingredients were ground through a 5.0 mm sieve. A total of 2,592 Hy-Line Brown laying hens at 210 days of age were randomly divided into 6 groups with 6 replicates per group and 72 hens per replicate. Each group was fed diets containing corn ground to different particle sizes. The experimental period lasted 16 weeks. The results showed: 1) The geometric mean diameter of corn and complete diets increased with larger sieve diameters, though the difference in complete diets was smaller. Grinding energy consumption gradually decreased from 3.93 kW · h/t to 1.19 kW · h/t as sieve diameter increased. 2) As corn grinding particle size increased, average egg weight first increased then decreased, with the 5.0 mm sieve group

showing significantly higher average egg weight than the 10.0 mm sieve group ( $P < 0.05$ ). Broken egg rate and soft egg rate first decreased then increased with larger particle sizes; the 6.0 mm sieve group had significantly lower broken egg rate than the 10.0 mm sieve group ( $P < 0.05$ ), while the 7.0 mm sieve group had significantly lower soft egg rate than the 4.0 mm sieve group ( $P < 0.05$ ). 3) The 7.0 mm sieve group exhibited significantly greater yolk ratio than the 5.0 mm sieve group ( $P < 0.05$ ). 4) The 5.0 mm sieve group showed significantly higher apparent digestibility of crude protein than the 6.0, 7.0, 8.0, and 10.0 mm sieve groups ( $P < 0.05$ ), significantly higher apparent digestibility of gross energy than the 4.0, 7.0, and 10.0 mm sieve groups ( $P < 0.05$ ), and the 7.0 mm sieve group demonstrated significantly higher apparent digestibility of dry matter than the 4.0 and 10.0 mm sieve groups ( $P < 0.05$ ). 5) The 7.0 mm sieve group had significantly lower cecal *Escherichia coli* counts than the 4.0 and 10.0 mm sieve groups ( $P < 0.05$ ), the 5.0 mm sieve group showed significantly higher jejunum index than the 6.0, 7.0, and 8.0 mm sieve groups ( $P < 0.05$ ), the 8.0 mm sieve group had significantly lower chyme pH in the proventriculus than the 4.0 and 5.0 mm sieve groups ( $P < 0.05$ ), and the 6.0 mm sieve group exhibited significantly higher chyme pH in the ileum than the 4.0, 5.0, 7.0, and 10.0 mm sieve groups ( $P < 0.05$ ). In conclusion, for laying hen diets, grinding corn with a 6.0 mm sieve diameter optimizes production performance and egg quality while promoting intestinal health.

**Keywords:** corn grinding particle size; laying hens; grinding energy consumption; performance; egg quality; digestive function

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## Introduction

Grinding is a critical process in feed manufacturing for laying hens. Corn constitutes approximately 60% of the diet, representing a major component. Grinding corn makes diets easier to digest and absorb, improves nutrient utilization efficiency, promotes growth, and reduces digestive tract diseases [1-4]. Feed intake is related to grinding particle size, and many studies have shown that coarser particle sizes can increase feed intake without significantly affecting production performance [5-7]. However, research on the optimal corn grinding particle size in complete diets for laying hens is limited both domestically and internationally. The national standard for layer feed in China specifies that feed for laying hens must pass through a 4.00 mm woven sieve, with no more than 15% retained on a 2.00 mm sieve, but this standard provides limited guidance for practical production. Commercial layer feed production typically uses sieve diameters of 5-8 mm. Production practice demonstrates that grinding technology and parameters directly affect processing costs and feed quality. Larger sieve diameters produce less uniform particle sizes, while smaller sieves create excessively fine particles and increase energy consumption. The various ingredients in layer feed differ significantly in particle size, shape, and density, making them prone to segregation. This leads to uneven nutrient distribution in feeders, affecting

both egg quality and production performance, while fine particles in the feed may not be fully consumed or utilized by the birds [8-11]. This experiment used six sieve diameters (4.0, 5.0, 6.0, 7.0, 8.0, and 10.0 mm) to grind corn and investigated the effects of different corn grinding particle sizes and distributions on production performance, egg quality, and digestive function in laying hens. The objective was to identify the optimal corn grinding particle size for peak production, improve laying performance and feed efficiency, and reduce grinding energy consumption, providing a reference for commercial layer feed production.

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### 1.1 Experimental Design

A single-factor experimental design was employed. A total of 2,592 Hy-Line Brown laying hens at 210 days of age were randomly allocated into 6 groups with 6 replicates per group and 72 hens per replicate. The basal diet was formulated according to NRC (1994) [12] and the Chinese Feeding Standard of Chickens (NY/T 33-2004). The composition and nutrient levels of the basal diet are shown in Table 1. In the experimental diets, corn was ground using a hammer mill with sieve diameters of 4.0, 5.0, 6.0, 7.0, 8.0, and 10.0 mm, while other major ingredients were ground through a 5.0 mm sieve. The experiment was conducted at the Beijing Pinggu Shuangyin Poultry Farm. Hens were housed in three-tier cages with ad libitum access to feed and water. The house was kept clean and well-ventilated, with controlled temperature and regular disinfection. After a 4-day adaptation period, the formal experimental period lasted 16 weeks.

**Table 1** Composition and nutrient levels of the basal diet (air-dry basis)

*Notes: 1) The premix provided the following per kilogram of diet: Cu 8 mg, Zn 40 mg, Fe 70 mg, Mn 30 mg, I 0.175 mg, Se 0.075 mg, VA 10,800 IU, VD 2,160 IU, VK 1.0 mg, VE 4.6 mg, VB 5 mg, VB 6 mg, calcium pantothenate 5 mg, niacin 7 mg, folic acid 0.1 mg. 2) ME, CP, and ash were measured values, while others were calculated values.*

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### 1.2 Measurement Methods

**1.2.1 Grinding Particle Size** During diet processing, three samples of each ground corn and soybean meal particle size were collected, and three mixed samples were taken from each group. Samples were sealed in self-sealing bags for later analysis. Geometric mean particle diameter was determined using the fourteen-layer sieve method specified in the national standard GB 6971-1986 (Feed Grinder Test Methods).

**1.2.2 Grinding Energy Consumption** Grinding energy consumption ( $\text{kW} \cdot \text{h/t}$ ) was calculated as:

$$1.732 \times \cos \phi \times U \times I \times T$$

where: U = voltage; I = current;  $\cos \phi = 0.8$ ; T = time.

**1.2.3 Production Performance** During the experiment, daily feed intake, egg number, egg weight, broken eggs, soft-shell eggs, and mortality were recorded per replicate. Average egg weight (AEW), laying rate, feed-to-egg ratio (F/E), broken egg rate, and soft egg rate were calculated for the experimental period.

**1.2.4 Egg Quality** At the end of weeks 4, 8, 12, and 16, 10 eggs were randomly selected from each replicate to measure egg weight, egg shape index, shell strength, yolk color, Haugh unit, yolk index, and shell thickness.

**Shell thickness measurement:** Shells from the large end, small end, and middle of each egg were collected. The inner membrane was removed with tweezers, and thickness was measured at three points using an eggshell thickness gauge, with the average value calculated.

**Egg shape index:** Calculated as egg length/egg width.

**Thick albumen height measurement:** Three equidistant points between the yolk edge and thick albumen edge (avoiding chalazae) were measured using an albumen height gauge, and the average was calculated.

**Haugh unit:** Calculated as:

$$100 \times \log(H - 1.7W^{0.37} + 7.57)$$

where: H = thick albumen height (mm), W = egg weight (g).

**Yolk color measurement:** Yolk color was measured using a Lab Scan XE colorimeter to determine lightness (L), redness (a), and yellowness (b\*) values.

**1.2.5 Apparent Nutrient Digestibility** At the end of week 16, excreta were collected to determine apparent digestibility of crude protein, dry matter, and gross energy using the acid-insoluble ash method. Crude protein content was determined by the Kjeldahl method according to GB/T 6432-1994. Gross energy was measured using an IKA2000 standard bomb calorimeter. Dry matter content was determined according to GB/T 6435-2014.

**1.2.6 Cecal Microbial Counts** At the end of the experiment, two hens per replicate were slaughtered. The cecum was ligated at both ends, excised, disinfected with alcohol cotton, placed in a sterile plastic bag, and transported in an ice box to the microbiology laboratory for enumeration of *Escherichia coli*, *Lactobacillus*, and *Salmonella*.

Cecal microbial counts were determined according to GB/T 4789-2010. Cecal digesta was diluted with sterile saline, vortexed for 3-5 minutes, and serially diluted  $10^3$  to  $10^6$  fold. Each dilution was plated in six replicates (100  $\mu$ L) on selective media. *Salmonella* was cultured on TPY agar at 37°C anaerobically for 48-72 h; *Lactobacillus* on Lactobacillus medium at 37°C anaerobically for 48 h; and *E. coli* on Eosin Methylene Blue (EMB) agar at 37°C aerobically for 24 h. After incubation, bacteria were identified based on colony morphology and Gram staining. The most appropriate dilution was selected for plate counting, and results were expressed as log colony-forming units per gram of digesta (lg CFU/g).

**1.2.7 Intestinal Mucosal Morphology** At the end of the experiment, duodenum, jejunum, and ileum samples were collected from two hens per replicate, fixed, and processed for paraffin sectioning for microscopic observation and photography.

**Villus height:** Measured from villus tip to the junction with crypt cells (forming a sharp angle), with 10 villi measured per sample and averaged.

**Crypt depth:** Measured from crypt base to the opening between adjacent villi, with 10 crypts measured per sample and averaged.

**Intestinal wall thickness:** Measured from external surface to the junction of muscularis and submucosa (serosa plus muscularis thickness), with 10 measurements per sample and averaged.

**1.2.8 Digestive Tract Chyme pH and Organ Indices** At the end of the experiment, two hens per replicate were slaughtered. The weights of gizzard, proventriculus, duodenum, jejunum, and ileum were recorded, and chyme pH in each segment was measured. Digestive organ index was calculated as organ weight (g) per live body weight (kg).

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### 1.3 Statistical Analysis

Experimental data were analyzed by one-way ANOVA using SPSS 18.0 and SAS 9.2. Data are presented as “mean  $\pm$  standard deviation.” Differences among group means were tested for significance using Duncan’s multiple comparison test, with  $P < 0.05$  as the significance threshold. Graphs were generated using Excel 2016 and SAS 9.2.

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### 2.1 Geometric Mean Diameter and Particle Size Distribution of Corn and Complete Diets

As shown in Table 2 and Figure 1 [Figure 1: see original paper], the geometric mean diameter of corn increased progressively with larger sieve diameters, with

the percentage of large particles ( $>2,360 \text{ }\mu\text{m}$ ) increasing markedly to 13.77%, 22.42%, 42.69%, 49.10%, 50.36%, and 59.15%, respectively.

**Table 2** Geometric mean diameter of corn

*Note: In the same column, values with different superscript letters differ significantly ( $P < 0.05$ ), while values with the same or no superscript letters do not differ significantly ( $P > 0.05$ ). The same applies to Table 3.*

As shown in Table 3 and Figure 2 [Figure 2: see original paper], the geometric mean diameter of complete diets increased gradually with larger sieve diameters, following the same trend as ground corn, but the differences were substantially smaller, with a wider particle size distribution range that was more prone to segregation.

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## 2.2 Effects of Different Corn Grinding Particle Sizes on Grinding Energy Consumption

As shown in Figure 3 [Figure 3: see original paper], grinding energy consumption per ton of corn decreased gradually with increasing sieve diameter, following a non-linear relationship. Non-linear regression analysis yielded the equation:

$$y = 7.4792e^{-0.193x} \quad (R^2 = 0.947)$$

F-test results showed  $P < 0.0001$ , indicating the equation was highly significant.

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## 2.3 Effects of Different Corn Grinding Particle Sizes on Production Performance of Laying Hens

As shown in Table 4, average egg weight first increased then decreased with larger corn grinding particle sizes, with the 5.0 mm sieve group showing the highest average egg weight, significantly greater than the 10.0 mm sieve group ( $P < 0.05$ ) but not different from other groups ( $P > 0.05$ ). Broken egg rate and soft egg rate first decreased then increased; the 6.0 mm sieve group had the lowest broken egg rate, significantly lower than the 10.0 mm sieve group ( $P < 0.05$ ), while the 7.0 mm sieve group had the lowest soft egg rate, significantly lower than the 4.0 mm sieve group ( $P < 0.05$ ). No significant differences were observed in laying rate or feed-to-egg ratio among groups ( $P > 0.05$ ), though feed-to-egg ratio followed a decreasing then increasing trend, and laying rate followed an increasing then decreasing trend, with the 6.0 mm sieve group showing the lowest feed-to-egg ratio and highest laying rate.

**Table 4** Effects of different grinding particle sizes of corn on performance of laying hens

Note: In the same row, values with different superscript letters differ significantly ( $P < 0.05$ ), while values with the same or no superscript letters do not differ significantly ( $P > 0.05$ ). The same applies below.

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## 2.4 Effects of Different Corn Grinding Particle Sizes on Egg Quality of Laying Hens

As shown in Table 5, no significant differences were observed in eggshell strength, shell thickness, egg shape index, or Haugh unit among groups ( $P > 0.05$ ). Yolk ratio first increased then decreased with larger grinding particle sizes, with the 7.0 mm sieve group showing the highest yolk ratio, significantly greater than the 5.0 mm sieve group ( $P < 0.05$ ) but not different from other groups ( $P > 0.05$ ). Yolk color parameters ( $L$ ,  $a$ ,  $b$ ) showed irregular trends. The 8.0 mm sieve group had the lowest  $L$  value, significantly lower than the 4.0 and 5.0 mm sieve groups ( $P < 0.05$ ). The 10.0 mm sieve group had the highest  $a^*$  value, significantly higher than the 4.0, 5.0, and 6.0 mm sieve groups ( $P < 0.05$ ). The 7.0 mm sieve group had the highest  $b^*$  value, significantly higher than the 4.0, 5.0, 6.0, and 10.0 mm sieve groups ( $P < 0.05$ ).

**Table 5** Effects of different grinding particle sizes of corn on egg quality of laying hens

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## 2.5 Effects of Different Corn Grinding Particle Sizes on Nutrient Apparent Digestibility of Laying Hens

As shown in Table 6, apparent digestibility of crude protein, gross energy, and dry matter first increased then decreased with larger grinding particle sizes. The 5.0 mm sieve group showed the highest crude protein digestibility, significantly higher than the 6.0, 7.0, 8.0, and 10.0 mm sieve groups ( $P < 0.05$ ) but not different from the 4.0 mm sieve group ( $P > 0.05$ ). The 5.0 mm sieve group also showed the highest gross energy digestibility, significantly higher than the 4.0, 7.0, and 10.0 mm sieve groups ( $P < 0.05$ ). The 7.0 mm sieve group showed the highest dry matter digestibility, significantly higher than the 4.0 and 10.0 mm sieve groups ( $P < 0.05$ ).

**Table 6** Effects of different grinding particle sizes of corn on nutrient apparent digestibility of laying hens (%)

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### 2.6.1 Cecal Microbial Counts

As shown in Table 7, no significant differences were observed in cecal *Lactobacillus* counts among groups ( $P > 0.05$ ). *Escherichia coli* counts first decreased then increased with larger grinding particle sizes, with the 7.0 mm sieve group

showing the lowest count, significantly lower than the 4.0 and 10.0 mm sieve groups ( $P < 0.05$ ). *Salmonella* was not detected in any group.

**Table 7** Effects of different grinding particle sizes of corn on cecal microbes number of laying hens (lg CFU/g)

*Note:* - = not detected.

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### 2.6.2 Intestinal Mucosal Morphology

As shown in Table 8, no significant differences were observed in duodenal villus height, crypt depth, villus height/crypt depth (V/C) ratio, or jejunal crypt depth among groups ( $P > 0.05$ ). The 5.0 mm sieve group showed the greatest jejunal villus height, significantly higher than the 8.0 mm sieve group ( $P < 0.05$ ). The 7.0 mm sieve group showed the greatest ileal villus height, significantly higher than the 4.0 mm sieve group ( $P < 0.05$ ), and also the greatest ileal crypt depth, significantly higher than the 4.0 mm sieve group ( $P < 0.05$ ). The 10.0 mm sieve group showed the lowest jejunal V/C ratio, significantly lower than the 4.0 mm sieve group ( $P < 0.05$ ), while the 8.0 mm sieve group showed the lowest ileal V/C ratio, significantly lower than the 5.0, 6.0, and 10.0 mm sieve groups ( $P < 0.05$ ).

**Table 8** Effects of different grinding particle sizes of corn on intestinal mucosa organization structure of laying hens

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### 2.6.3 Digestive Organ Indices

As shown in Table 9, the 5.0 mm sieve group showed the highest jejunum index, significantly higher than the 6.0, 7.0, and 8.0 mm sieve groups ( $P < 0.05$ ). No significant differences were observed in gizzard index, proventriculus index, duodenum index, ileum index, or liver index among groups ( $P > 0.05$ ).

**Table 9** Effects of different grinding particle sizes of corn on digestive organ index of laying hens

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### 2.6.4 Digestive Tract Chyme pH

As shown in Table 10, no significant differences were observed in chyme pH of gizzard, duodenum, or jejunum among groups ( $P > 0.05$ ). The 8.0 mm sieve group showed the lowest chyme pH in the proventriculus, significantly lower than the 4.0 and 5.0 mm sieve groups ( $P < 0.05$ ). The 6.0 mm sieve group showed the highest chyme pH in the ileum, significantly higher than the 4.0, 5.0, 7.0, and 10.0 mm sieve groups ( $P < 0.05$ ).

**Table 10** Effects of different grinding particle sizes of corn on digestive tract chyme pH of laying hens

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### 3.1 Effects of Different Corn Grinding Particle Sizes on Production Performance of Laying Hens

The Chinese national standard for layer feed specifies that feed must pass through a 4.00 mm woven sieve, with no more than 15% retained on a 2.00 mm sieve. Commercial production typically uses 5.0-8.0 mm sieves. Wang et al. [13] investigated corn-based diets ground with 5.0, 7.0, and 8.0 mm sieves and found no significant effects on production performance, though some effects on dry matter and crude protein digestion were observed. Gao et al. [14] reported that increasing corn grinding particle size from 600  $\mu$ m to 1,500  $\mu$ m significantly increased feed intake and showed trends toward increased laying rate and average egg weight. Zhang [15] studied different corn grinding particle sizes (671.56, 824.97, and 1,001.7  $\mu$ m) and found that laying rate and feed intake increased significantly with larger particle sizes, feed-to-egg ratio followed a decreasing then increasing trend, but average egg weight was not significantly affected. Our results showed that laying rate and average egg weight first increased then decreased, while feed-to-egg ratio, broken egg rate, and soft egg rate generally followed a decreasing then increasing trend with larger grinding particle sizes. Overall, using a 6.0 mm sieve diameter improved production performance, consistent with Gao et al. [14] and Zhang [15] but extending their particle size ranges. Coarser diets may improve performance because hens prefer pecking larger particles, which provide mechanical stimulation to the gizzard, enhancing digestive activity. Longer retention time allows more complete digestion and absorption, thereby improving performance. Excessively fine diets provide insufficient stimulation for gastrointestinal motility, impairing digestion. The gizzard's grinding function makes extremely fine grinding unnecessary.

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### 3.2 Effects of Different Corn Grinding Particle Sizes on Egg Quality of Laying Hens

Egg shape index directly affects fertility, hatchability, and transport safety, with standard values of 1.30-1.35. Eggshell strength is important for transport and storage. Shell thickness positively correlates with shell strength, with optimal thickness of 0.33-0.35 mm. Yolk color significantly influences commercial value. The Haugh unit measures albumen quality and egg freshness, with fresh eggs scoring above 80; it is an important international standard for egg quality evaluation. Yolk ratio reflects the proportion of yolk to whole egg, with higher values indicating better egg quality. Hamilton et al. [16] and Deaton et al. [17] reported no significant differences in Haugh unit or shell strength when feeding diets with 814-873  $\mu$ m corn, consistent with our results. However, Saffa et

al. [18] found no effect of grinding particle size (774, 922, and 1,165  $\mu\text{m}$ ) on yolk ratio in Lohmann hens, while Zhang et al. [19] reported that larger particle sizes increased yolk ratio. Our results showed that shell strength, shell thickness, and yolk ratio generally followed an increasing then decreasing trend with larger particle sizes, while yolk color showed no clear pattern. No significant differences were observed in egg shape index or Haugh unit among groups, possibly due to differences in laying rates or hen breeds.

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### 3.3 Effects of Different Corn Grinding Particle Sizes on Cecal Microbial Counts and Nutrient Apparent Digestibility

The cecum is an important fermentation site containing numerous microbial populations. Under normal conditions, beneficial bacteria such as *Lactobacillus* are dominant, but pathogen challenge can alter this balance, affecting nutrient absorption and immune function. Zhang et al. [20] reported that most amino acid digestibility values first increased then decreased with larger grinding particle sizes in broilers. Li et al. [21] found that 449 and 529  $\mu\text{m}$  particle sizes improved crude protein and dry matter digestibility compared to 210 and 334  $\mu\text{m}$ . Canibe et al. [22] showed that coarsely ground diets stimulated *Lactobacillus* growth in the gastrointestinal tract. Our results demonstrated that apparent digestibility of crude protein, gross energy, and dry matter generally followed an increasing then decreasing trend with larger particle sizes. Cecal *Lactobacillus* counts followed a similar pattern, while *E. coli* counts followed a decreasing then increasing trend, consistent with Engberg et al. [23]. Appropriate grinding particle size improves microbial balance by stimulating gizzard and proventriculus activity, prolonging retention time, and optimizing pH conditions. Pathogens entering orally are reduced by the acidic environment of the gizzard and proventriculus, promoting beneficial bacteria growth. Longer retention time and slower flow rate compared to finely ground diets may allow more complete digestion, improving nutrient digestibility. Excessively fine diets reduce gastrointestinal stimulation, impairing digestive secretion and microbial balance, while overly coarse diets increase digestive burden and reduce pathogen elimination by the gizzard.

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### 3.4 Effects of Different Corn Grinding Particle Sizes on Digestive Function of Laying Hens

Our study showed that different corn grinding particle sizes affected proventriculus and ileum pH, with proventriculus pH first decreasing then increasing and ileum pH being highest in the 6.0 mm sieve group, while other gastrointestinal pH values were unaffected. Most digestive organ indices were not significantly affected. Zhang [15] reported no significant effects of corn grinding particle size (using 3.0, 4.0, and 5.0 mm sieves) on chyme pH in proventriculus, giz-

zard, jejunum, or ileum, while duodenal pH first decreased then increased. Liu et al. [24] found that 1.5 mm ground pellets promoted duodenum, jejunum, and ileum development in 1-21 day-old broilers, while 2.5 mm pellets promoted proventriculus development in 22-42 day-old broilers, with larger particle sizes improving gizzard and duodenum development. Healy [25] reported that 900  $\mu$ m diets increased gizzard, proventriculus, and intestinal weights compared to 300  $\mu$ m diets in broilers. These differences from our results may be due to residual chyme during organ weighing. Finely ground diets can cause gizzard underdevelopment and proventriculus hypertrophy, while coarsely ground diets increase gizzard size and gastric acid secretion, possibly to enhance muscular adaptation for grinding or to increase capacity. Overly coarse diets may overburden digestive organs and cause damage.

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## Conclusion

1. As sieve diameter increased, the geometric mean diameter of corn increased progressively, with a wider particle size distribution and a markedly higher percentage of large particles ( $>2,360 \mu$ m).
2. With larger corn grinding particle sizes, various production performance, egg quality, and digestive function indicators first increased then decreased. Comprehensive analysis suggests that a 6.0 mm sieve diameter for grinding corn in layer diets optimizes production performance, egg quality, and digestive tract health.

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