RESEARCH ARTICLE
AGROBIOLOGICAL RECORDS
ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

EFFECTS OF COARSE AND FINE GROUND CORN PARTICLE SIZE DISTRIBUTION ON PHYSICAL CHARACTERISTICS AND NUTRIENT DIGESTIBILITY OF LAYER DIETS

Riska Sri Wahyuni Haris [1], Sri Purwanti [2,3] and Jasmal Ahmari Syamsu [2,4,5,*]

[1]Master's Program in Animal Science and Technology, Faculty of Animal Science, Universitas Hasanuddin, Makassar, Indonesia
[2]Faculty of Animal Science, Universitas Hasanuddin, Makassar, Indonesia
[3]Poultry Nutrition and Feed Research Group, Universitas Hasanuddin, Makassar, Indonesia
[4]Feed Technology and Industry Research Group, Universitas Hasanuddin, Makassar, Indonesia
[5]Center of Research and Development for Livestock Resources and Tropical Animals, Universitas Hasanuddin, Makassar, Indonesia

*_Corresponding author_: jasmal.syamsu@unhas.ac.id

ABSTRACT

Corn particle size distribution is an important factor influencing the physical characteristics of feed and nutrient utilization in poultry diets. This study evaluated the effects of different corn particle size distributions on feed physical characteristics, nutrient composition, and in vitro nutrient digestibility, and identified the most suitable particle size distribution to balance feed physical characteristics and nutrient utilization in layer diets. The study was conducted in two sequential stages. Stage I characterized the particle size distribution of hammer-milled corn and evaluated its physical characteristics, including bulk density and angle of repose. Stage II evaluated seven dietary treatments containing different proportions of coarse and fine corn particles. Nutrient composition was analyzed using Near Infrared Reflectance Spectroscopy (NIRS), whereas in vitro protein and starch digestibility were determined by enzymatic digestion. Hammer-milled corn was dominated by coarse particles (86.43%), whereas fine particles accounted for only 13.57% of the total sample. Particle size exhibited a positive relationship with bulk density and a negative relationship with angle of repose, indicating that coarse particles possessed superior packing efficiency and flowability. Corn particle size distribution significantly affected protein and starch digestibility ($P<0.05$). The highest protein digestibility was observed in the diet containing 25% coarse particles and 75% fine particles (69.56%), whereas the highest starch digestibility was obtained in the diet containing 100% fine particles (76.86%). Among the treatments evaluated, the diet containing 25% coarse particles and 75% fine particles provided the most suitable overall response by combining the highest protein digestibility, high starch digestibility, and favorable feed physical characteristics. These findings suggest that balancing coarse and fine particle proportions, rather than maximizing either fraction individually, may represent an effective strategy for improving feed characteristics and nutrient utilization in layer diets.

Keywords: Corn particle size distribution, Feed physical quality, Bulk density, Angle of repose, Protein digestibility, Starch digestibility, Layer diets.

Article History: ABR-26-226 || Received: 14-Jun-2026 || Revised: 24-Jun-2026 || Accepted: 10-Jul-2026 || Published Online: 14-Jul-2026

1. INTRODUCTION

Corn is the primary energy source in poultry diets and remains the most widely used cereal grain in laying hen nutrition due to its high metabolizable energy content, palatability, and availability (Liu et al., 2020; Moseri et al., 2025; Nemati et al., 2025). In commercial layer diets, corn commonly accounts for approximately 40–60% of the total feed formulation, making its nutritional and physical characteristics critical determinants of feed quality and production efficiency. In addition to supplying energy through its high starch content, corn also provides valuable bioactive compounds, including carotenoids, which contribute to egg yolk pigmentation and overall egg quality (Moreno et al., 2020; Gunjević et al., 2023; Djulardi et al., 2024). Consequently, variations in corn quality may directly influence nutrient utilization, feed efficiency, egg quality, and productive performance in laying hens (Cheneri et al., 2026).

Citation: Haris RSW, Purwanti S and Syamsu JA, 2026. Effects of coarse and fine ground corn particle size distribution on physical characteristics and nutrient digestibility of layer diets. Agrobiological Records 25: 70-78. https://doi.org/10.47278/journal.abr/2026.048

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

Because corn is typically ground before incorporation into poultry diets, grinding is one of the most important operations in feed manufacturing. Grinding determines particle size distribution, which subsequently influences feed processing efficiency, particle uniformity, and overall feed quality (Córdova-Noboa et al., 2021; Lyu et al., 2022). Furthermore, particle size has been recognized as an important factor affecting gastrointestinal development and nutrient utilization in poultry (Mtei et al., 2019; Selim et al., 2024). Therefore, optimizing corn particle size has become an important consideration in modern poultry nutrition due to its influence on both feed manufacturing processes and digestive physiology.

Beyond its effects on digestive physiology, corn particle size distribution plays a fundamental role in determining the physical characteristics of poultry diets. Feed containing a wide range of particle sizes is more susceptible to segregation during handling, transportation, storage, and feed delivery, resulting in differences between the formulated diet and the nutrients actually consumed by laying hens (Nunnenkamp et al., 2022). Moreover, particle size influences several physical quality attributes, including flowability, bulk density, pellet durability, pellet hardness, and storage efficiency (Córdova-Noboa et al., 2021; Syamsu et al., 2025). Previous studies have demonstrated that increasing particle size improves feed flowability and reduces angle of repose, indicating more efficient handling and storage characteristics of granular feed materials (Friesen et al., 2024). Fine particles generally improve feed uniformity and pellet cohesion, whereas excessively coarse particles may increase segregation and selective feeding behavior, particularly in mash diets (Nunnenkamp et al., 2022). Therefore, maintaining an appropriate particle size distribution is essential for preserving feed homogeneity and physical quality throughout feed manufacture and delivery.

The influence of corn particle size on nutrient digestibility has been extensively investigated, although the reported responses remain inconsistent. Fine grinding increases the surface area available for enzyme–substrate interactions, thereby facilitating starch and protein digestion and potentially enhancing nutrient availability (Sonu et al., 2022). However, excessive particle size reduction may impair gizzard development and reduce the mechanical stimulation required for optimal gastrointestinal function (Mtei et al., 2019). Recent studies have demonstrated that the inclusion of coarse corn in poultry diets can stimulate gizzard development, enhance digestive function, and improve nutrient utilization and growth performance (Akram et al., 2025). In contrast, coarse particles stimulate gizzard enlargement, increase digesta retention time, promote reverse peristalsis, and enhance digestive activity, thereby potentially improving nutrient utilization despite providing less surface area for enzymatic hydrolysis (Rueda et al., 2024; Liu et al., 2026). Previous studies have reported contrasting responses of laying hens to different corn particle sizes, ranging from improvements in nutrient digestibility and feed efficiency to negligible effects on egg production and performance (Yenice et al., 2025). These inconsistencies indicate that the relationship between corn particle size and nutrient utilization in laying hens is not yet fully understood.

Despite considerable research on feed particle size in poultry nutrition, several important knowledge gaps remain. Most previous studies have focused primarily on production performance, egg quality, feed efficiency, or feed form, whereas comparatively few have examined how corn particle size distribution influences the physical characteristics of layer diets and how these changes subsequently affect nutrient digestibility. Furthermore, conflicting findings regarding the relative advantages of fine and coarse grinding suggest that the mechanisms linking particle size, feed physical properties, and nutrient utilization remain unclear (Yenice et al., 2025; Liu et al., 2026). In addition, studies evaluating feed physical characteristics have often focused on individual parameters or on feed manufacturing efficiency, without comprehensively integrating particle size distribution, feed physical quality, and nutrient digestibility within a single experimental framework (Nunnenkamp et al., 2022). Consequently, a more integrated evaluation of these relationships is required to develop practical recommendations for corn-grinding strategies in laying hen nutrition.

Therefore, the present study was conducted to evaluate the effects of coarse- and fine-ground corn particle size distributions on the physical characteristics and nutrient digestibility of layer diets. It was hypothesized that differences in corn particle-size distribution would significantly alter feed physical characteristics and, in turn, affect nutrient digestibility. The findings of this study are expected to provide scientific information to optimize corn grinding practices and improve feed quality and nutrient utilization in laying hen production systems.

2. MATERIALS AND METHODS

2.1. Experimental Design

This study was conducted in two sequential experimental stages. The first stage aimed to characterize the particle-size distribution of hammer-milled corn and to evaluate its physical characteristics. The second stage used the particle fractions obtained in the first stage to formulate layer diets with different proportions of coarse and fine corn particles, and subsequently evaluated nutrient composition, in vitro protein digestibility, and in vitro starch digestibility.

Citation: Haris RSW, Purwanti S and Syamsu JA, 2026. Effects of coarse and fine ground corn particle size distribution on physical characteristics and nutrient digestibility of layer diets. Agrobiological Records 25: 70-78. https://doi.org/10.47278/journal.abr/2026.048

2.2. Stage I: Characterization of Ground Corn Particle Size Distribution and Physical Characteristics

***2.2.1. Corn Sample Collection and Particle Size Classification*:** Ground corn samples were obtained from a commercial corn processing facility located in Sidenreng Rappang Regency, South Sulawesi, Indonesia. The corn was ground using a hammer mill, the most widely used grinding system in poultry feed manufacturing. Particle size distribution was determined using a sieve shaker equipped with a series of standard sieves. For each determination, a 500-g sample of ground corn was sieved for 5 minutes. A total of 200 subsamples collected during routine milling operations were analyzed to obtain representative particle-size distribution data for hammer-milled corn produced by the commercial processing facility. The sieve series consisted of openings of 2.00, 1.68, 1.00, 0.84, 0.71, 0.59, 0.42, 0.297, 0.250, and 0.149 mm.

Particle size distribution was expressed as the percentage of the sample retained on each sieve relative to the total sample weight. For the purpose of particle fractionation in this study, particles retained on mesh sizes 10–20 (2.00–0.84 mm) were grouped as the coarse fraction, whereas particles retained on mesh sizes 26–100 (0.71–0.149 mm) were grouped as the fine fraction. The resulting coarse and fine fractions were subsequently used as experimental materials in Stage II.

***2.2.2. Bulk Density Determination*:** Bulk density was determined according to the procedures described by Syamsu et al. (2015). Samples of each particle size fraction were placed into a graduated cylinder of known volume without external compaction. The filled container was weighed, and the net sample weight was calculated by subtracting the empty container's weight. Bulk density was calculated using the following equation:

$$\mathrm{BD} = \frac{W}{V}$$

where:

- BD = bulk density (kg m^{-3})
- W = weight of sample (kg)
- V = volume occupied by the sample (m^3)

2.2.3. Angle of Repose Determination: The angle of repose was measured using the funnel method following the procedure described by Syamsu et al. (2015). Approximately 200 g of the sample was allowed to flow freely through a plastic funnel positioned 15 cm above a flat surface, forming a conical pile. Each determination was conducted in triplicate. The height (h) and diameter (d) of the pile were measured using a ruler, and the angle of repose (α) was calculated using the following equation:

$$\alpha = \tan^{-1}\left(\frac{2h}{d}\right)$$

where: α = angle of repose (°); h = pile height (cm); d = pile diameter (cm)

2.2.4. Statistical Analysis: Particle size distribution data were analyzed descriptively. The relationships between particle size and the physical characteristics of ground corn, including bulk density and angle of repose, were evaluated using simple linear regression analysis. Statistical analyses were performed using IBM SPSS Statistics version 26.0.

2.3. Stage II: Evaluation of Nutrient Composition and In Vitro Digestibility

2.3.1. Experimental Diet Formulation: The coarse and fine corn particle fractions obtained in Stage I were used to formulate the experimental layer diets. Based on the sieve classification, coarse particles were defined as particles ranging from 0.84 to 2.00 mm, whereas fine particles were defined as particles ranging from 0.149 to 0.71 mm. All diets consisted of 50% ground corn, 30% commercial layer concentrate, and 20% rice bran. Diet formulation was designed to meet the nutrient requirements of laying hens in accordance with the Indonesian National Standard for layer diets (BSN, 2024). Seven dietary treatments were prepared with three replicates per treatment: R0 = commercial ground corn without sieving (market sample); R1 = unsieved hammer-milled corn (1.0–3.2 mm); R2 = 100% coarse particles (0.84–2.00 mm); R3 = 100% fine particles (0.149–0.71 mm); R4 = 75% coarse particles + 25% fine particles; R5 = 50% coarse particles + 50% fine particles; and R6 = 25% coarse particles + 75% fine particles.

The experimental diets were prepared by thoroughly mixing the designated corn fractions with commercial layer concentrate and rice bran, in accordance with the treatment formulations. Representative samples of each dietary treatment were collected and analyzed for moisture, crude protein, crude fat, crude fiber, ash, calcium, phosphorus, and metabolizable energy using Near Infrared Reflectance Spectroscopy (NIRS). Instrument calibration and prediction procedures were conducted in accordance with standard feed evaluation protocols and referenced to AOAC (2009). All analyses were performed in triplicate, and the mean values obtained were used to characterize the nutrient composition of the experimental diets. The analyzed nutrient composition of the experimental diets is presented in Table 1. Overall, the diets were formulated to provide comparable nutrient levels, with differences among treatments primarily reflecting the proportions of coarse and fine corn particles rather than ingredient composition.

Table 1: Analyzed the nutrient composition of experimental diets formulated with different corn particle size distributions

Nutrient Composition	R0	R1	R2	R3	R4	R5	R6
Moisture (%)	12.14 ± 0.10	12.27 ± 0.06	12.26 ± 0.19	12.64 ± 0.17	12.19 ± 0.17	12.49 ± 0.18	12.62 ± 0.16
Ash (%)	9.85 ± 1.70	11.90 ± 0.48	11.03 ± 1.32	10.67 ± 1.74	9.80 ± 0.96	9.82 ± 1.51	11.30 ± 0.22
Crude Protein (%)	15.89 ± 0.32	15.03 ± 0.15	15.02 ± 0.23	15.98 ± 0.21	15.61 ± 0.25	15.97 ± 0.34	16.02 ± 0.62
Crude Fat (%)	4.83 ± 0.27	4.87 ± 0.90	4.54 ± 0.56	5.46 ± 0.54	4.33 ± 0.18	4.93 ± 0.51	5.37 ± 0.13
Crude Fiber (%)	3.47 ± 0.12	3.29 ± 0.08	3.14 ± 0.14	3.23 ± 0.10	3.17 ± 0.13	3.23 ± 0.99	3.34 ± 0.27
Metabolizable Energy (kcal/kg)	3765.94 ± 14.64	3721.22 ± 68.91	3728.16 ± 32.70	3842.12 ± 29.03	3813.75 ± 35.42	3806.94 ± 50.86	3840.93 ± 51.64
Calcium (%)	1.59 ± 1.14	3.31 ± 1.16	2.82 ± 0.55	2.36 ± 1.15	1.99 ± 0.93	1.67 ± 1.20	2.94 ± 1.18
Phosphorus (%)	0.61 ± 0.05	0.71 ± 0.04	0.63 ± 0.09	0.74 ± 0.10	0.57 ± 0.04	0.66 ± 0.08	0.78 ± 0.03

R0 = Commercial ground corn without sieving (market sample); R1 = Unsieved hammer-milled corn (1.0–3.2 mm); R2 = 100% coarse particles (0.84–2.00 mm); R3 = 100% fine particles (0.149–0.71 mm); R4 = 75% coarse particles + 25% fine particles; R5 = 50% coarse particles + 50% fine particles; and R6 = 25% coarse particles + 75% fine particles.

2.3.3. Determination of In Vitro Protein Digestibility: *In vitro* protein digestibility was determined using the multi-enzyme procedure of Boisen & Fernández (1997) with modifications based on Cervantes-Pahm & Stein (2010). Briefly, 0.500 g of the feed sample was weighed into incubation tubes and mixed with phosphate buffer and hydrochloric acid solutions. Pepsin solution and chloramphenicol were subsequently added to simulate gastric digestion, and samples were incubated at 39°C for 2 h. Following gastric digestion, phosphate buffer and sodium hydroxide solutions were added to adjust the pH for the intestinal digestion phase. Samples were further incubated before the addition of EDTA and Viscozyme® enzyme solution. The final incubation was conducted at 39°C for 18 h to simulate post-gastric digestion. At the end of the incubation period, undigested residues were recovered by filtration and analyzed for residual crude protein. In vitro protein digestibility was calculated as the proportion of digested protein relative to the total crude protein content of the sample. All analyses were performed in triplicate.
***2.3.4. Determination of In Vitro Starch Digestibility*:** In vitro starch digestibility was determined according to the procedure described by Setiana et al. (2015), with modifications to simulate enzymatic starch digestion under controlled laboratory conditions. Approximately 200 mg of the feed sample was mixed with 0.02 M phosphate buffer, calcium chloride solution, and sodium azide solution. Samples were incubated at 40°C for 1 h before the addition of pancreatic α-amylase enzyme solution. During enzymatic digestion, aliquots were collected at predetermined intervals and centrifuged at 8,000 rpm for 5 min. The resulting supernatant was incubated with amyloglucosidase at 50°C to hydrolyze dextrins to glucose. Glucose concentration was determined using the glucose oxidase–peroxidase (GOPOD) method. Starch digestibility was calculated as the proportion of glucose released relative to the sample's total starch content and expressed as a percentage. All analyses were performed in triplicate.
***2.3.5. Statistical Analysis*:** Data were analyzed using one-way analysis of variance (ANOVA) according to the procedures described by Steel et al. (1997). When significant treatment effects were detected ($P<0.05$), treatment means were separated using Duncan's Multiple Range Test. Statistical analyses were performed using IBM SPSS Statistics version 26.0

3. RESULTS AND DISCUSSION

3.1. Particle Size Distribution and Physical Characteristics of Ground Corn

The particle size distribution of hammer-milled corn used in this study is presented in Table 2. Coarse particles (0.84–2.00 mm) constituted 86.43% of the total sample, whereas fine particles (0.149–0.71 mm) accounted for only 13.57%. The predominance of coarse particles indicates that the hammer milling process produced relatively large particle fractions, resulting in a heterogeneous particle-size distribution that may influence both the feed's physical characteristics and nutrient utilization. The predominance of coarse particles is consistent with the operating characteristics of hammer mills commonly used in feed manufacturing. Particle size distribution in hammer-milled corn is influenced by factors including screen size, grain moisture content, and milling intensity (Mustakin et al., 2021). Consequently, a considerable proportion of coarse particles is often retained after grinding, especially when larger screen openings are used.

The physical characteristics of hammer-milled corn particles at different particle sizes are presented in Table 3. Bulk density decreased progressively as particle size decreased, whereas the angle of repose increased with decreasing particle size. The largest particle fraction (>2.00 mm) exhibited the highest bulk density (710 kg m^{-3}) and the lowest angle of repose (18.79°), whereas the smallest particle fraction (0.25 mm) exhibited the lowest bulk density (467 kg m^{-3}) and the highest angle of repose (49.65°).

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

Table 2: Particle size distribution of hammer-milled corn used in the study

Mesh size	Particle size (mm)	Distribution (%)	Classification
<10	>2.00	33.07	Coarse
10	2.00	15.98	Coarse
12	1.68	24.19	Coarse
18	1.00	4.14	Coarse
20	0.84	9.05	Coarse
26	0.71	2.11	Fine
30	0.59	3.80	Fine
40	0.42	3.48	Fine
50	0.297	2.90	Fine
60	0.250	1.20	Fine
100	0.149	0.07	Fine

These results indicate that smaller particles exhibited lower packing efficiency and poorer flow characteristics than larger particles. The greater surface area-to-volume ratio of fine particles increases interparticle friction and cohesive forces, restricting particle rearrangement and resulting in a less compact bulk structure. Consequently, fine particles occupied a greater volume relative to their mass, leading to lower bulk density and higher angle of repose values. Similar relationships between bulk density, angle of repose, and particle interaction properties have been reported in corn-based granular systems. Boac et al. (2023) demonstrated that increases in friction-related parameters reduced bulk density while increasing angle of repose, confirming the importance of particle interaction characteristics in determining bulk flow behavior. Baidhe and Clementson (2026) demonstrated that interparticle friction, particle morphology, and rolling resistance significantly influence bulk packing behavior and angle of repose in granular corn systems. Their findings indicated that increased frictional interactions restrict particle movement and rearrangement, resulting in less efficient packing and reduced flowability. Similar findings were reported by Braun et al. (2021), who observed that reducing hammermill screen size produced finer corn particles with higher angles of repose and reduced flowability. Likewise, Blazer et al. (2024) reported that smaller processed corn particles exhibited lower bulk density and poorer handling characteristics than coarser particles.

Table 3: Physical characteristics of hammer-milled corn particles at different particle sizes

Mesh size	Particle size (mm)	Bulk density (kg m^{-3})	Angle of repose (°)
<10	>2.00	710 ± 28.34	18.79 ± 1.50
10	2.00	659 ± 27.60	25.66 ± 2.17
12	1.68	590 ± 11.86	32.45 ± 2.19
18	1.00	551 ± 14.18	24.27 ± 3.15
20	0.84	525 ± 14.06	33.56 ± 1.38
26	0.71	506 ± 20.52	42.26 ± 2.54
30	0.59	534 ± 12.25	38.11 ± 2.72
40	0.42	505 ± 11.08	40.25 ± 3.01
50	0.297	483 ± 9.15	45.27 ± 2.13
60	0.250	467 ± 13.12	49.65 ± 1.43

Regression analysis further confirmed the strong influence of particle size on the physical properties of hammer-milled corn. Bulk density increased linearly with increasing particle size (Fig. 1), with particle size explaining 88.13% of the observed variation ($R^2 = 0.8813$). Conversely, the angle of repose decreased as particle size increased (Fig. 2), with particle size accounting for 70.04% of the variation in flow behavior ($R^2 = 0.7004$). These findings demonstrate that particle size is a major determinant of the packing behavior, handling characteristics, and flow properties of ground corn and should therefore be carefully considered in feed manufacturing and storage operations.

3.2. In Vitro Protein Digestibility

The effects of different corn particle size distributions on in vitro protein digestibility are presented in Table 4. Analysis of variance indicated that dietary treatments significantly affected protein digestibility ($P<0.05$). Protein digestibility values ranged from 63.82% to 69.56%, indicating that changes in the proportions of coarse and fine corn particles altered the accessibility of dietary protein to enzymatic hydrolysis. The highest protein digestibility was observed in treatment R6 (25% coarse particles + 75% fine particles). However, Duncan's multiple range test indicated that R6 was statistically comparable to R1 and R3, which also exhibited relatively high protein digestibility values. Conversely, R4 produced the lowest protein digestibility and differed significantly from R6.

The higher protein digestibility observed in diets containing a greater proportion of fine particles may be attributed to the increased surface area available for enzymatic hydrolysis. Reduction in particle size exposes a larger proportion of the protein matrix to digestive enzymes, thereby facilitating protein degradation and increasing nutrient availability. Similar observations have been reported in poultry nutrition studies, where finer grinding improved nutrient accessibility and enhanced digestive utilization by increasing the contact area between feed particles and digestive enzymes (Mtei et al., 2019; Sonu et al., 2022).

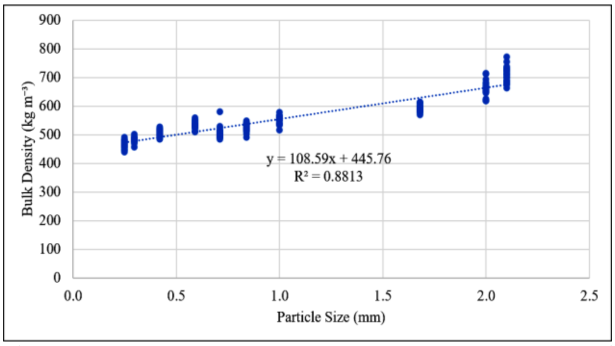

Fig. 1: Relationship between particle size and bulk density of hammer-milled corn.

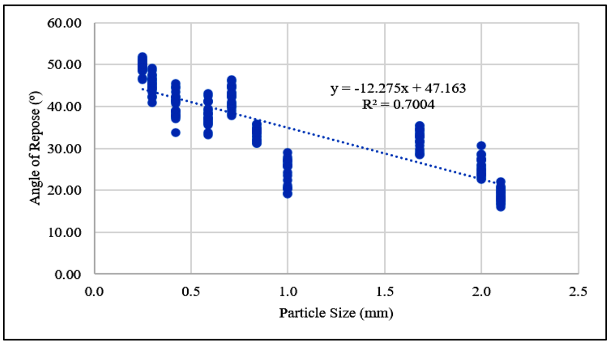

Fig. 2: Relationship between particle size and angle of repose of hammer-milled corn.

Table 4: Effects of Corn Particle Size Distribution on In Vitro Protein and Starch Digestibility of Layer Diets

Treatment	Protein Digestibility (%)	Starch Digestibility (%)
R0	65.89 ± 0.83bc	48.96 ± 7.11c
R1	68.55 ± 1.89ab	46.93 ± 3.51cd
R2	64.91 ± 0.02bc	38.75 ± 2.46d
R3	68.48 ± 1.82ab	76.86 ± 1.79a
R4	63.82 ± 1.96c	44.03 ± 0.86cd
R5	66.42 ± 0.04b	47.86 ± 7.67cd
R6	69.56 ± 0.04a	60.85 ± 7.12b

Mean ± SD within a column with different alphabets differ significantly according to Duncan's Multiple Range Test (P<0.05). R0 = Commercial ground corn without sieving (market sample); R1 = Unsieved hammer-milled corn (1.0–3.2 mm); R2 = 100% coarse particles (0.84–2.00 mm); R3 = 100% fine particles (0.149–0.71 mm); R4 = 75% coarse particles + 25% fine particles; R5 = 50% coarse particles + 50% fine particles; and R6 = 25% coarse particles + 75% fine particles.

Although coarse particles may promote gizzard development and prolong digesta retention time under in vivo conditions, the present study used an in vitro enzymatic digestion system that did not represent the mechanical contribution of the gastrointestinal tract. This interpretation is supported by Novotný et al. (2026), who reported that broilers fed coarse diets exhibited greater gizzard development and higher nitrogen retention than birds fed finer diets, indicating that coarse particles may enhance nutrient utilization through physiological adaptations of the gastrointestinal tract. Consequently, the greater accessibility of protein in finely ground corn appeared to exert a stronger influence on protein hydrolysis than the potential digestive advantages associated with coarse particles. Nevertheless, the relatively narrow range of protein digestibility values across treatments suggests that corn particle-size distribution had a moderate effect on protein digestion. Furthermore, the overlapping statistical groups observed among R6, R1, and R3 suggest that increasing the proportion of fine particles beyond a certain threshold may yield only limited additional improvements in protein digestibility.

3.3. In Vitro Starch Digestibility

The effects of different corn particle size distributions on in vitro starch digestibility are presented in Table 4. Dietary treatments significantly affected starch digestibility (P<0.05), with values ranging from 38.75 to 76.86%. The highest starch digestibility was observed in treatment R3 (100% fine particles), whereas the lowest value occurred in R2 (100% coarse particles). Duncan's multiple range test showed that R3 formed a distinct statistical group and exhibited significantly greater starch digestibility than all other treatments. Conversely, R2 had the lowest digestibility and differed significantly from treatments with higher proportions of fine particles. Intermediate treatments containing combinations of coarse and fine particles produced digestibility values between these two extremes.

The higher starch digestibility observed in diets containing a greater proportion of fine particles may be attributed to the increased exposure of starch granules to enzymatic hydrolysis. Grinding reduces particle size and disrupts the physical structure of the corn endosperm, thereby increasing the surface area available for α-amylase activity. Consequently, starch becomes more accessible to enzymatic attack and glucose release, resulting in improved digestibility. This interpretation is consistent with the findings of Li et al. (2025), who reported that starch digestibility was closely associated with average particle size and starch structural characteristics. Their study demonstrated that smaller starch particles were more readily gelatinized and exhibited greater susceptibility to enzymatic hydrolysis due to enhanced water penetration and increased accessibility of starch granules. Similar observations have been reported by Mtei et al. (2019), who demonstrated that reducing corn particle size can enhance nutrient utilization by increasing the accessibility of feed substrates to digestive enzymes.

This explanation is further supported by Yenice et al. (2025), who indicated that finer grinding increases the surface area available for enzymatic action, thereby improving nutrient utilization. In addition, Paneru et al. (2026) emphasized that the efficiency of starch digestion largely depends on the accessibility of starch granules to enzymatic hydrolysis, which directly influences energy utilization in laying hens. The distinct separation of R3 from the other treatments in the Duncan test further indicates that starch digestion was highly responsive to particle-size reduction. Therefore, the higher starch digestibility observed in diets containing a greater proportion of fine particles demonstrates that particle size distribution plays an important role in determining starch availability and the efficiency of starch digestion in layer diets.

3.4. Optimization of Corn Particle Size Distribution

The present study demonstrated a clear trade-off between feed physical characteristics and nutrient digestibility in response to changes in corn particle size distribution. Increasing the proportion of coarse particles improved bulk density and flowability, as indicated by higher bulk density values and lower angles of repose. Conversely, increasing the proportion of fine particles enhanced protein and starch digestibility because of the greater surface area available for enzymatic hydrolysis. These findings indicate that no single particle fraction could simultaneously maximize all response variables.

The treatments containing extreme particle distributions exhibited contrasting responses. Diets composed predominantly of coarse particles exhibited superior physical characteristics but lower nutrient digestibility, whereas diets containing exclusively fine particles achieved the highest starch digestibility but offered fewer advantages in feed handling and flowability. Similar relationships between particle size, nutrient utilization, and feed functionality have been reported in poultry nutrition studies (Rueda et al., 2024; Yenice et al., 2025).

Among the treatments evaluated, R6 (25% coarse particles and 75% fine particles) provided the most balanced response. This treatment produced the highest protein digestibility and maintained starch digestibility at a level significantly higher than that observed in diets dominated by coarse particles, although lower than the value observed in the 100% fine-particle treatment (R3). At the same time, the inclusion of a moderate proportion of coarse particles contributed to better physical characteristics than those observed in diets composed entirely of fine particles. These results suggest that incorporating a limited proportion of coarse particles may provide structural benefits without substantially reducing nutrient availability.

From a practical feed manufacturing perspective, the findings indicate that balancing coarse and fine particle fractions may be more advantageous than maximizing either fraction individually. A particle size distribution consisting of 25% coarse particles and 75% fine particles appears to provide an appropriate compromise between feed physical quality and nutrient digestibility. Therefore, this particle size distribution may be considered a suitable strategy to improve feed-handling characteristics while maintaining efficient nutrient utilization in layer diets.

4. CONCLUSION

Corn particle size distribution significantly influenced the physical characteristics and nutrient digestibility of layer diets. Increasing the proportion of coarse particles improved bulk density and flowability, whereas increasing the proportion of fine particles enhanced protein and starch digestibility. The results demonstrated a clear trade-off between feed physical characteristics and nutrient digestibility, indicating that no single particle fraction could maximize all response variables simultaneously.

Among the treatments evaluated, the diet containing 25% coarse particles (0.84–2.00 mm) and 75% fine particles (0.149–0.71 mm) yielded the most balanced response across physical characteristics and nutrient digestibility. This particle size distribution produced the highest protein digestibility while maintaining relatively high starch digestibility and acceptable physical characteristics. Therefore, combining coarse and fine corn particles may be a practical strategy to improve feed quality and nutrient utilization in layer diets. Further studies under in vivo conditions are required to validate the effects of this particle size distribution on nutrient utilization, laying performance, feed efficiency, and egg production characteristics.

Declarations

Funding: This research received no external funding.

Acknowledgement: The authors would like to express their sincere gratitude to the Master's Program in Animal Science and Technology, Faculty of Animal Science, Hasanuddin University, the Feed Technology and Industry Laboratory, Faculty of Animal Science, Hasanuddin University, and PT Charoen Pokphand Indonesia Tbk, Makassar, for their assistance and support during the conduct of this research.

Conflicts of Interest: The authors declare that there is no conflict of interest regarding the publication of this manuscript.

Data Availability: All data generated or analyzed during this study are included in this published article.

Ethics Statement: The authors declare that this manuscript is original, free from plagiarism, and has not been published or submitted elsewhere for publication.

Author's Contributions: Riska Sri Wahyuni Haris was responsible for conducting the research, collecting and analyzing data, performing laboratory analyses, interpreting the results, and preparing the original manuscript draft. Sri Purwanti contributed to research methodology, supervision, data interpretation, critical review, and editing of the manuscript. Jasmal Ahmari Syamsu conceived the study, provided overall academic supervision, contributed to data interpretation, critically reviewed the manuscript, and approved the final version for publication. All authors have read and agreed to the published version of the manuscript.

Generative AI Statement: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

REFERENCES

Akram, M. Z., Sureda, E. A., Corion, M., Comer, L., Zhao, H., Schroyen, M., & Everaert, N. (2025). Effects of coarse corn or oat hulls on growth performance, intestinal health, and microbiota modulation in underperforming broilers. Animal Nutrition, 23, 153–166. https://doi.org/10.1016/j.aninu.2025.04.012

AOAC International (2009). Official methods of analysis of AOAC International (18th Ed., Rev. 2). AOAC International.

Baidhe, E., & Clementson, C. L. (2026). Corn contact parameter calibration and optimization for variable particle shape application in DEM simulation of high moisture corn kernel. Smart Agricultural Technology, 14, 102087. https://doi.org/10.1016/j.atech.2026.102087

Blazer, K. J., Shinners, K. J., Kluge, Z. A., Tekeste, M. Z., & Digman, M. F. (2024). Physical properties of moist, fermented corn grain after processing by grinding or milling. AgriEngineering, 6(2), 908–924. https://doi.org/10.3390/agriengineering6020052

Boac, J. M., Casada, M. E., Pordesimo, L. O., Petingco, M. C., Maghirang, R. G., & Harner, J. P., III. (2023). Evaluation of particle models of corn kernels for discrete element method simulation of shelled corn mass flow. Smart Agricultural Technology, 4, 100197. https://doi.org/10.1016/j.atech.2023.100197

Boisen, S., & Fernández, J. A. (1997). Prediction of the total tract digestibility of energy in feedstuffs and pig diets by in vitro analyses. Animal Feed Science and Technology, 68(3–4), 277–286. https://doi.org/10.1016/S0377-8401(97)00058-8

Braun, M., Dunmire, K., Evans, C., Stark, C., Woodworth, J., & Paulk, C. (2021). Effects of Grinding Corn with Different Moisture Content on Subsequent Particle Size and Flowability. Processes, 9(8), 1372. https://doi.org/10.3390/pr9081372

BSN (2024). Pakan ayam ras petelur - Bagian 5: Masa produksi (layer). SNI 8290-5-2024. Badan Standarisasi Nasional, Indonesia. https://akses-sni.bsn.go.id/sni

Cervantes-Pahm, S. K., & Stein, H. H. (2010). Ileal digestibility of amino acids in conventional, fermented, and enzyme-treated soybean meal and in soy protein isolate, fish meal, and casein fed to weanling pigs. Journal of Animal Science, 88(8), 2674–2683. https://doi.org/10.2527/jas.2009-2677

Cheneri, C. K., Riveros, R., Silva, R. L., Lima, I. L., Franco, J. R. G., Shurson, G. C., & Sakomura, N. K. (2026). Evaluation of corn high protein dried distiller grains inclusion in laying hens' diets to enhance or maintain egg production and egg quality through extended storage time. Journal of Applied Poultry Research, 35(2), Article 100699. https://doi.org/10.1016/j.japr.2026.100699

Córdova-Noboa, H. A., Oviedo-Rondón, E. O., Ortiz, A., Matta, Y., Hoyos, J. S., Buitrago, G. D., Martinez, J. D., Yanquen, J. J., Chico, M., San Martin, V. E., Fahrenholz, A., Ospina-Rojas, I. C., & Peñuela, L. (2021). Effects of corn kernel hardness and grain drying temperature on particle size and pellet durability when grinding using a roller mill or hammermill. Animal Feed Science and Technology, 271, 114715. https://doi.org/10.1016/j.anifeedsci.2020.114715

Djulardi, A., Triani, H. D., & Yuniza, A. (2024). Study of avocado seed and banana peel processing as corn element substitution in Japanese quail (Coturnix-coturnix japonica) ration. International Journal of Veterinary Science, 13(1), 42-50. https://doi.org/10.47278/journal.ijvs/2023.058

Friesen, W. G., Otto, H. K., Stark, C. R., & Paulk, C. B. (2024). Effects of grinding and pelleting Kernza grain on subsequent particle size, flowability, and pellet durability index. Journal of Applied Poultry Research, 33(4), 100447. https://doi.org/10.1016/j.japr.2024.100447

Gunjević, V., Grbeša, D., Zurak, D., Kiš, G., Janječić, Z., Svečnjak, Z., Bedeković, D., Duvnjak, M., Pirgozliev, V., & Kljak, K. (2023). Effect of maize hybrid in complete feed on the production performance and economic considerations in laying hens. Sustainability, 15(22), 15748. https://doi.org/10.3390/su152215748

Li, X., Yan, J., Gao, J., Xing, F., Gu, Q., Zhao, C., & Liu, J. (2025). Structure, physicochemical properties and in vitro digestibility of starch in corn flour with different milling processes. Food Chemistry: X, 30, 102901. https://doi.org/10.1016/j.fochx.2025.102901

Liu, W., Yan, X. G., Yang, H. M., Zhang, X., Wu, B., Yang, P. L., & Ban, Z. B. (2020). Metabolizable and net energy values of corn stored for 3 years for laying hens. Poultry Science, 99(8), 3914–3920. https://doi.org/10.1016/j.psj.2020.03.041

Liu, Y., Liu, R., Yang, J., Zhang, F., Liu, Y., Yang, X., Sun, R., Xi, Y., Ren, Z., & Yao, J. (2026). Sequential carry-over effects of corn particle size in brooding phase and feed form in growing phase on full-cycle performance of laying hens. Poultry Science, 105(6), 106815. https://doi.org/10.1016/j.psj.2026.106815

Lyu, F., Hendriks, W. H., van der Poel, A. F. B., & Thomas, M. (2022). Particle size distribution, energy consumption, nutrient composition and in vitro ileal digestion characteristics of hammer milled maize and soybean meal affected by moisture content. Animal Feed Science and Technology, 288, 115317. https://doi.org/10.1016/j.anifeedsci.2022.115317

Moreno, J. A., Díaz-Gómez, J., Fuentes-Font, L., Angulo, E., Gosálvez, L. F., Sandmann, G., Portero-Otin, M., Capell, T., Zhu, C., Christou, P., & Nogareda, C. (2020). Poultry diets containing (keto) carotenoid-enriched maize improve egg yolk color and maintain quality. Animal Feed Science and Technology, 260, 114334. https://doi.org/10.1016/j.anifeedsci.2019.114334

Moseri, H., Belonwu, E.N., Iwegbu, A., & Gbayisomore, O.S. (2025). Impact of cassava peels and palm kernel cake meal on the Hemato-biochemical parameters, performance, and economics of finisher pigs. Agrobiological Records, 19, 12-18. https://doi.org/10.47278/journal.abr/2025.002

Mtei, A. W., Abdollahi, M. R., Schreurs, N. M., & Ravindran, V. (2019). Impact of corn particle size on nutrient digestibility varies depending on bird type. Poultry Science, 98(11), 5504–5513. https://doi.org/10.3382/ps/pez206

Mustakin, M., Purwanti, S., & Syamsu, J. A. (2021). Particle size and physical characteristic of corn milling results using hammer mill as poultry feed ingredients. World Journal of Advanced Research and Reviews, 11(2), 298–302. https://doi.org/10.30574/wjarr.2021.11.2.0401

Nemati, M., Ahmadi, F., Daneshyar, M., & Lotfollahian, H. (2025). Does the type of cereal grain in the diet influence egg quantity and quality measures of laying hens without the use of carbohydrases? Poultry Science Journal, 13(2), 253–260. https://doi.org/10.22069/psj.2025.23064.2219

Novotný, J., Cumplík, L., Horáková, L., Řiháček, M., Zálešáková, D., Šťastník, O., Mrkvicová, E., Kumbar, V., & Pavlata, L. (2026). Effect of different feed particle size on digestive tract morphology, digesta viscosity, nutrient retention, and blood biochemical parameters in slow-growing broiler chickens. Veterinary and Animal Science, 33, 100715. https://doi.org/10.1016/j.vas.2026.100715

Nunnenkamp, D., Bierschenk, E., Westendarp, H., & Wolf, P. (2022). Particle size distribution of organic complete diets for laying hens during feed offering. Agriculture, 12(2), 272. https://doi.org/10.3390/agriculture12020272

Paneru, D., White, D., Sharma, M., Gonzalez, J., & Kim, W. (2026). Effect of replacing conventional corn with corn containing thermostable α-amylase enzyme (AMY797E) in standard and low-energy diets in laying hens. Animals, 16(4), 582. https://doi.org/10.3390/ani16040582

Rueda, K. M., Stark, C. R., Paulk, C. B., & Rochell, S. J. (2024). Evaluation of particle size and feed form on performance, carcass characteristics, nutrient digestibility, and gastrointestinal tract development of broilers at 39 d of age. Poultry Science, 103, 103437. https://doi.org/10.1016/j.psj.2024.103437

Selim, L., Ataku, K., & Tharwat, M. (2024). Ensilage characteristics of corn silage treated with fermented green juice prepared from corn, alfalfa or timothy. International Journal of Agriculture and Biosciences, 13(3), 276-279. https://doi.org/10.47278/journal.ijab/2024.109

Setiana, I., Utomo, D.B., & Ramli, N. (2015). Pengaruh ukuran partikel jagung terhadap kecernaan pati: In vitro. Bul. Makanan Ternak, 102 (1), 27–35.

Sonu, Singh, Y., Chahal, U., Kaur, D., & Malik, D. S. (2022). Impact of maize particle size on egg production and egg quality of White Leghorns in early stage of production. Indian Journal of Animal Sciences, 92(12), 1451–1455. https://doi.org/10.56093/ijans.v92i12.126948

Steel, R. G. D., Torrie, J. H., & Dickey, D. A. (1997). Principles and Procedures of Statistics: A Biometrical Approach (3rd ed.). McGraw-Hill.

Syamsu, J.A., Amal, I., Wijaya, A., Amas, A.F., Walinono, A.M.F.A., Yamin, A.A., & Purwanti, S. (2025). Optimization of ground corn particle size in the diet to improve physical pellet quality in native chicken feed production. International Journal of Agriculture and Biosciences 14(6), 1438–1445. https://doi.org/10.47278/journal.ijab/2025.166

Syamsu, J.A., Yusuf, M., & Abdullah, A. (2015). Evaluation of Physical Properties of Feedstuffs in Supporting the Development of Feed Mill at Farmers Group Scale. Journal of Advanced Agricultural Technologies, 2(2), 147-150.

Yenice, E., Çenesiz, A. A., Çiftci, İ., Ceylan, N., Toprak, N. N., & Yavaş, İ. (2025). Effects of particle size and feed form on the performance, egg quality, digestive organs and plumage condition in laying hens. Poultry Science, 104(7), 105230. https://doi.org/10.1016/j.psj.2025.105230

Citation: Haris RSW, Purwanti S and Syamsu JA, 2026. Effects of coarse and fine ground corn particle size distribution on physical characteristics and nutrient digestibility of layer diets. Agrobiological Records 25: 70-78. https://doi.org/10.47278/journal.abr/2026.048