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Effects of Corn Particle Sizes on Growth Performance and Gastrointestinal Morphology of Broiler Chickens

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ABSTRACT

This study was conducted to determine the effect of corn particle sizes on broiler performance, carcass characteristics and intestinal morphology during growing stage. Forty five broiler chickens were brooded for 21 days and thereafter divided into three treatment groups. Each group were fed different level of corn particle sizes (fine = 0.96 mm, medium = 1.22 mm and coarse = 1.60 mm). Each treatment was replicated five times (3 birds/replicate). The experiment was conducted from day 21 to day 42 of age (week 4 - week 6). At d 42, all birds were slaughtered and eviscerated for carcass and intestinal morophölgy analysis. The results showed that corn particle size level did not affect average daily gain (ADG) (g/day) at the end of week 4 (range from 73.57-75.18 g/day), week 5 (range from 77.39-81.9 g/day) and week 6 (range from 68.57-72.65 g/day); feed conversion ratio (g/g) at the end of week 4 (range from 1.53-1.55), week 5 (range from 1.62-1.87) and week 6 (range from 2.16-2.32); cumulative feed intake (g) at the end of week 4 (range from 796-808 g) week 5 (range from 1007-1050 g) and week 6 (range from 1085.8-1159.0g). In addition, no effect was pronounced on dressing percentage yield (range from 73.9-75.1%) and gastrointestinal relative organ weight and gastrointestinal relative length and weight with exception for small intestine. Broilers fed medium corn particle sizes (i.e 1.22 mm) had a lower relative weight and relative length weight (2.49 g/kg of BW and 24.99 cm/kg of BW, respectively) compared to broiler fed fine particle sizes (0.94 mm) (2.71 g/kg of BW and 27.13 cm/kg of BW, respectively) and coarse particle sizes (1.6 mm) (2.78 g/kg of BW and 27.82 cm/kg of BW, respectively). It can be concluded that coarse milling of corn grains above the recommended particle sizes have no influence on overall growth parameters in broiler chicken during grower stage. However, subsequent processing steps (such as mixing and pelleting) may be compromised and should be investigated when incorporating coarse particles sizes in poultry diets.

Keywords: Particle size, growth performance, gastrointestinal morphology, broiler.

INTRODUCTION

Recommendations regarding optimum particle sizes for broiler feed have been contradictory as the results from feeding trials are confounded by a number of factors. These factors include feed physical form, complexity of the diet, grain type, endosperm hardness, grinding method, pellet quality and particle size distribution (Jahan *et al.,* 2006; Amerah *et al.,* 2007; Khoa, 2007; Kaczmarek *et al.,* 2013; Amerah *et al.,* 2008). Although, grain grinding is considered to posses many advantages in feed processing such as facilitate mixing of ingredient to produce uniform compound feed (Koch, 1996), increase surface area of feed particles which improve their digestibility and nutritive

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value (Al-Rabadi *et al.,* 2009), and increase nutrient enrichment after ground grains being segregated by sieving (Al-Rabadi, 2013, a, b). Amerah *et al*. (2007) reported that the optimum particle sizes in broiler diet should range from 0.6 to 0.9 mm. However, fine-milling can increase the feed production cost by increasing the cost of energy consumed for millers per unit mass of milled grains. Cost of feed manufacturing is divided among feed formulation and feed form while grain milling constitutes the second largest energy expenditure (Reece *et al.,* 1985). Wondra *et al* (1995) reported that production capacity of hammer mill increased by two folds when average corn particle size increased from 0.42 mm to 0.82 mm. Increasing production capacity of feed mill and reducing energy consumption and cost during milling could be effective approaches to reduce feed cost (Wondra *et al.,* 1995; Al-Rabadi, 2013 a, b). This can be achieved by coarse milling of grains. However, coarse milling above the recommended particle size (i.e 0.6-0.9 mm) may have consequences on growth performance of broilers (Khoa, 2007). The objective of this experiment was to evaluate the influence of degree of coarse milling of corn grains on growth performance and the changes in the digestive system in broiler chickens.

MATERIALS AND METHODS

Corn grinding and sieving analysis

Corn grains were hammer milled (Model No. M.K. 11R180, Kteingesellschaft, Germany) by using three levels of screen size: 2, 6 and 8 mm to produce three levels of particle sizes: fine, medium and coarse particles, respectively. Ground corn was collected at steady state while milling (constant motor load indicated by constant ammeter reading). The ground corn was segregated by size using vertical multiple sieving under gravity with mechanical agitation using a sieve shaker (Model No. SV001, Impact Test Equipment Ltd, UK). Eight screen sieve (Impact Test Equipment Ltd, UK) sizes were selected to give a broad spectrum of particle size ranging from 4.0 mm to 0.045 mm (pan) as shown in Table 1. Ground corn was sieved and the geometric mean diameter (d_{gw}) and geometric standard deviation (S_{gw}) were determined with 100 g sample according to American Society of Agricultural Biological Engineers Standards (ASAE) (2003) using a sieve shaker for 15 min. In this paper, the term particle sizes refers to particles that were retained on a particular sieve. Thus a particle size of 1.0 mm means that the particles in that fraction passed through the 2 mm sieve, and were retained on the 1.0 mm sieve. A particle size of <0.125 mm means that the material passed through the 0.125 mm sieve and was collected on the pan. Average particle sizes (d_{gw}), geometric standard deviation (S_{gw}), and fraction yield percentage are shown in Table (1).

Table 1. Means (± SD) of particle sizes distribution, average particle sizes (d_{gw}) and geometric stranded deviation (S_{gw}) of corn grains milled at different hammer mill screen sizes.

		Hammer mill screen size	
Sieve size (mm)	**2 mm**	**6 mm**	**8 mm**
	Fraction yield (%)±SD	Fraction yield (%)±SD	Fraction yield (%)±SD
4	0.15 ± 0.22	2.03 ± 0.58	16.03 ± 1.54
2.8	1.53 ± 0.15	9.03 ± 0.40	13.05 ± 1.12
2	11.44 ± 0.01	19.32 ± 0.16	15.82 ± 0.89

1	42.99 ± 0.001	35.85 ± 0.18	28.52 ± 1.37
0.5	23.64 ± 1.05	19.12 ± 2.57	14.87 ± 0.04
0.25	14.74 ± 0.07	12.42 ± 3.48	9.79 ± 1.78
0.125	5.44 ± 0.91	2.13 ± 0.72	1.82 ± 0.01
0.045	0.10 ± 0.001	0.10 ± 0.001	0.10 ± 0.001
Particle size parameters			
d_{gw} (mm)[a]	0.94^{c} ± 0.01	1.22^{b} ± 0.03	1.60^{a} ± 0.03
S_{gw} (mm)	2.05^{b} ± 0.04	2.12^{b} ± 0.02	2.37^{a} ± 0.08

[a]Means within rows that do not have identical letters differ significantly (P<0.05)

Birds and diets formulation

Forty five broiler chickens were raised from day 21 to day 42 of age according to general commercial husbandry guides. Broilers were raised in cages laid on floor and equipped with trough drinkers and feeders in each cage. Feed and water were given ad lib and broilers were provided with a continuous light. All diets were isocaloric and isonitrogenous and mainly composed of corn-soybean meal diet to meet or exceed nutrient requirement of broilers as reported by poultry National Research Council (NRC, 1994) as shown in Table 2.

Table 2. Ingredient composition and calculated analysis (g/kg) of the basal diet (as fed basis).

Ingredient	**(g/kg)**
Corn	557.9
Soybean meal	270.8
Soybean oil	60.0
DCP [a]	22.1
Salt (NaCl)	1.9
Vit.+Min premix[b]	2.0
Myco Curb ®[c]	1.0
Brocon Concentrate® (35% cp) [d]	76.8
Methionine	4.0
Lysine	3.5
Calculated analysis[e]	**(g/kg)**
AMEn (kcal/kg)	3200
Crude protein	200.0
Crude fiber	34.9
Methionine	7.9
Lysine	14.1

Calcium	9.0
Available phosphorous	7.3
Sodium	1.85
Methionine + Cystine	10.0

[a] Contained 21% calcium and 20% phosphorous.

[b] Vitamin premix provided per kilogram of premix: Vitamin A,700,000 IU; vitamin D3, 150,000 IU; vitamin E, 75mg; vitamin B1, 100 mg; vitamin K, 175 mg; vitamin B5, 600 mg; manganese oxide, 4000 mg, ferrous sulphate, 9000 mg, zinc oxide, 6000 mg, magnisum oxide, 2500 mg, potassium iodide, 70 mg, sodium selenite, 125 mg, copper sulphate, 100 mg, cobalt sulphate, 50 mg, dicalcium phosphate, 7000 m, sodium chloride, 10000 mg.

[c] Mold inhibitor for animal feed (Kemin Industries, U.S.A)

[d]Brocon Concentrate® (Wafa, B. V., Alblasserdam, Holland)

[e]Calculated based on analyzed values of feed ingredients (feed composition tables) from poultry NRC (1994).

Experimental Design

A completely randomized experimental design was used, with 3 treatments (level of corn particle sizes), 5 replicates per treatment and 3 broilers per replicate. Statistical analysis was performed using Statistical Analysis System (SAS) software programs (v.9.1, SAS Institute, Cary, NC). Covariance analysis was used to remove the effect of initial body on measured values. For all analysis, the value of α was set to 0.05, the level used for statistical significance. All data were presented as means (± SD).

Parameters Measurements

At the end of the experimental period (day 42 of age), all broilers in the experimental unit (three broilers per replicate) were weighed for carcass and gastrointestinal tract. Birds were slaughtered by cutting their jugular veins, scalded in hot water for about a minute, and feathers were removed by defeathering machine. Birds were eviscerated and weighed to obtain their dressed carcass weights. Heart, gizzard, , spleen, abdominal fat, small intestine, and large intestine were removed and weighed using a sensitive electronic scale (± 0.01 gram). Dressed carcass and weights of the digestive system organs were expressed as percentages of the live body weights. The length of digestive system parts was measured using a tailor's tape. For each bird, pH measurements were obtained directly from the digesta contents in the lumen of gizzard and proventriculus using a digital pH meter (Model PL-600, EZDO, Taiwan).

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RESULTS AND DISCUSSION

The effect of hammer mill screen size on average particle sizes (d_{gw}), geometric standard deviation (S_{gw}) and the fraction yield on each sieve after sieving for ground corn are shown in Table 1. As expected, reducing hammer mill screen size significantly reduced $d_{gw.}$ The influence of smaller hammer mill screen size on d_{gw} is attributed to higher retention time of grains in grinding chamber which results in more exposure of grain fragments to milling blades. Similar influence of reducing hammer mill screen size on d_{gw} has been reported for different hammer milled grains such in sorghum (Owsley, *et al.,* 1981; Al-Rabadi, 2013, a), barley (Al-Rabadi, 2013, b) and wheat (Amerah *et al.,* 2007). As reported by Baker and Herman (2002), geometric standard deviation measures the distribution of particle size (i.e. by dividing and multiplying the d_{gw} by the S_{gw}, a range into which 68 percent of the particles will fall and can be calculated.

Thus, with a higher S_{gw} representing lower uniformity of particle size. In this study, milling corn grains using 8 mm hammer mill screen size resulted in higher heterogeneity in particle size distribution (S_{gw}=2.37) compared to corn grains milled by using 6 mm screen size (S_{gw}=2.12) or by using 2 mm hammer mill screen size (S_{gw}=2.05).

Influence of corn particle size on broiler performance over the growing period (from week 4 to week 6) is shown in Table 3. Particle sizes of corn did not significantly affect broiler feed intake, growth rate, and feed conversion ratio (FCR) during growing stage. Reducing feed particles size has been reported to increase surface area per unit mass for enzymatic digestion (Al-Rabadi *et al.,* 2009). Fine grinding of grains has been reported to increase enzymatic digestion of starch and thus increase metabolizable energy of corn based diet (Kilburn and Edwards, 2001) and wheat based diet (Peron *et al.,* 2005). However, feeding coarse corn particles for broiler has been reported to mask the positive influence of fine milled grains by different mechanisms which may eliminated any difference on over all broiler growth performance to occur in this study. These differences could be attributed to three mechanisms; firstly, coarse grinding of corn grain has been reported to enhance the efficiency of protein and lysine retention in poultry during the growing phase (Parsons *et al.,* 2006). Al-Rabadi (2009) reported that different grain particles sizes posses different kinetics of starch digestion because coarse particles have a low starch digestion rate. Synchronous absorption of glucose and amino acids by poultry can increase metabolizable energy delivery and may reduce amino acid oxidation and thus enhances protein retention (van den Borne *et al.*, 2007) which reflects on over all poultry growth performance. Secondly, coarse particles tend to have higher retention time in the digestive system which allow more time for digestion and absorption to take place (Carlos and Edwards, 1997; Amerah *et al.,* 2007). Thirdly, feeding behavior of birds fed on coarse particles can partially justify the beneficiary influence of feeding coarse particles. When feeding coarse particles, the total number of pecks per day to consume a certain amount of feed are reduced, consequently, reduce energy input by birds (Jensen *et al.,* 1962; Amerah *et al.,* 2007).

Table.3. Influence of corn particle sizes on the average daily gain (ADG), feed conversion ratio (FCR) and cumulative feed intake (CFI)of 4-to-6-week broiler

		Particle size		
	Fine	**Medium**	**Coarse**	**P value**
Initial body weight (g)	721.57[a] ± 26.43	729.13 ± 12.94	729.0 ±24.33	0.81
Final body weight (g)	2298.21 ± 118.74	2348.3 ± 92.97	2293.0± 5.75	0.64
Week 4				
ADG (g/day)	75.18 ± 9.46	74.74 ±5.23	73.57 ±5.25	0.93
FCR (g/g)	1.55 ± 0.13	1.53 ± 0.19	1.54 ±0.075	0.98
CFI (g)	808.06 ± 42.30	797.78 ± 56.24	796.50 ± 60.6	0.93

Week 5				
ADG (g/day)	77.39 ± 8.28	79.14 ±8.14	81.19 ± 10.0	0.79
FCR (g/g)	1.87 ± 0.23	1.86 ± 0.16	1.62 ± 0.22	0.98
CFI (g)	1007.8 ± 73.77	1023.9 ± 57.98	1050.0 ± 92.9	0.68
Week 6				
ADG (g/day)	72.65 ± 8.77	77.42 ± 9.92	68.57 ±12.37	0.43
FCR (g/g)	2.21 ± 0.22	2.16 ± 0.31	2.32 ± 0.48	0.76
CFI (g)	1122.7 ± 159.83	1159.1 ± 69.30	1085.8± 60.9	0.56
Week4-week6				
ADG (g/day)	75.07 ± 5.42	77.10 ±4.53	74.44 ±3.47	0.64
FCR (g/g)	1.82 ± 0.08	1.85 ± 0.156	1.88 ±0.149	0.77
CFI (g)	2853.9±163.15	2980.9±151.13	2932.6± 92.0	0.51

[a]Means within rows that do not have identical letters differ significantly (P<0.05)

Influence of corn particle sizes on broilers relative organ weight (as a percentage of live weight) is shown in Table 4. Dressing percentage, and weights of large intestine, spleen, heart, abdominal fat and gizzard (as a percent of live body weight) were not affected by the different corn particle sizes (Table 4). However, relative weight and relative length (table 5) of small intestine was significantly higher for broilers fed coarse and fine particle diets compared to broilers fed medium particle sizes diet. The reason behind the influence of coarse and fine particles on the higher relative weight and length of small intestine is not clear (Amerah *et al.,* 2007). Feeding coarse particle sizes is reported to be positively correlated with relative gizzard weight (Nir *et al.,* 1994). Similar trend is shown in this study. Many researchers reported that feeding coarse feed particles can stimulate gastric secretions and reduce proventriculus and gizzard pH (Cumming, 1994; Nir *et al.,* 1994; Gabreial *et al.,* 2003), however, slight positive tendency is reported in this study (Table 4). The lack of clear influence of feed particle size on gizzard pH content may be attributed to a high S_{gw} value (Amerah *et al.,* 2007). Size of feed particle has been shown to affect the development of digestive system segments in birds fed mash diets (Nir *et al.,* 1995; Gabriel *et al.,* 2003). Relative heart weight and relative abdominal fat weight were measured in this study to explore, indirectly, any influence of particle size on nutrient synchrony (i.e glucose has a sparing effect on amino acids) which has a consequences on protein and fat deposition (Weurding *et al.,* 2003; van den Borne *et al.,* 2007). However, in this study, no influence on relative heart weight and relative abdominal fat weight were found (Table 4). The influence of corn particle sizes on conformational characteristics (length of gastrointestinal tract) of broiler digestive system is shown in Table 5. It has reported that the correlation between body weight and the length of different parts of gastrointestinal tract is beneficiary for nutrients absorption resulting in heavier body weight (Khoa, 2007). In this study, conformational characteristics were not affected by different particle sizes diets except for relative weight (table 4) and relative length of small intestine (Table 5). The absence of any significant effect of particle sizes on conformational characteristics may be attributed to the fact that the gizzard empties its contents when particle sizes have been reduced to about 15 - 40 µm (Duke, 1994; Hetland *et al.,* 2002) which may eliminate any influence of corn particle sizes on conformational characteristics in broilers gastrointestinal tract.

These results suggest that coarse milling of corn grains (up to 1.6 mm) did not influence over all broiler performance which can be an approach to reduce feed production costs. However and from processing prospective, precautions must be taken into consideration if corn grains are coarsely milled. More control of consecutive processing steps may be compromised when incorporating coarse particles sizes in poultry diets. For example, particle size has been reported to significantly influence mixing quality and homogeneity of complete diet (Amornthewaphat *et al.*, 1998). In addition, pellet durability has been reported to decline when coarse particles are incorporated in the diet (Thomas *et al.*, 1997; Thomas et al., 1998).

Table 4. Influence of corn particle sizes on broilers dressing percentage yield , relative organs weight (as a percentage ± SD of live body weight (BW)), gizzard and proventriculus pH (Mean ± SD).

		Particle size		
	Fine	**Medium**	**Coarse**	**P value**
Dressing %	73.94 ± 2.03	75.01 ± 1.97	74.93 ± 0.89	0.56
Small intestine relative weight (g/kg of BW)	2.71[a] ± 0.06	2.49[b] ± 0.17	2.78[a] ± 0.18	0.02
Large intestine relative weight (g/kg of BW)	0.32 ± 0.039	0.311 ± 0.041	0.32 ± 0.035	0.92
Gizzard relative weight (g/kg of BW)	1.69 ± 0.093	1.78 ± 0.17	1.83 ± 0.046	0.17
Abdominal fat relative weight (g/kg of BW)	0.36 ± 0.11	0.32 ± 0.12	0.39 ± 0.81	0.57
Heart relative weight (g/kg of BW)	0.50 ± 0.06	0.50 ± 0.03	0.50 ± 0.02	0.96
Gizzard pH	3.87 ± 0.18	3.92 ± 0.19	3.63 ± 0.3	0.16
Proventriculus pH	5.06 ±0.43	4.98 ± 0.17	4.73 ± 0.19	0.21

Means within rows that do not have identical letters differ significantly (P<0.05)

Table 5. Length of digestive system parts relative to BW (Mean ± SD) of 42-day-old broilers fed diets with different particle sizes.

		Particle size		
	Fine	**Medium**	**Coarse**	**P value**
Pancreas Length (cm/kg of BW)	5.39[a] ± 0.07	5.24 ±0.42	6.25 ± 0.77	0.07
Small intestine length (cm/kg of BW)	27.13[a] ±0.60	24.99[b] ± 1.71	27.82[a] ±1.84	0.02
duodenum length (cm/kg of BW)	12.95 ± 1.49	12.93 ± 0.84	13.74 ± 1.06	0.47
Jejunum length (cm/kg of BW)	37.23 ± 1.48	35.41 ± 3.13	35.29 ± 0.88	0.28
Ileum length (cm/kg of BW)	26.17 ± 1.93	25.24 ± 2.10	24.46 ± 3.82	0.62
Large intestine (cm/kg of BW)	3.21 ± 0.39	3.11 ± 0.40	3.19 ± 0.34	0.91
Ceca length (cm/kg of BW)	9.05. ± 1.04	8.29 ± 0.27	8.99 ± 0.49	0.19

[a]Means within rows that do not have identical letters differ significantly (P<0.05)

CONCLUSION

The outcomes of this study suggested that coarse milling above the recommended level of corn particle sizes did not influence overall broiler growth performance gastrointestinal morophology, and gizzard and proventriculus pH during growing period in broiler chickens.

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تأثير أحجام حبيبات الذرة على كفاءة النمو والقياسات الشكلية للجهاز الهضمي في دجاج اللحم

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ملخص

تم إجراء التجربة لتحديد تأثير حجم حبيبات الذرة على كفاءة الإنتاج، وخصائص الذبيحة والقياسات الشكلية للقناة الهضمية خلال مرحلة النمو في دجاج اللحم. تم تربية 45 طير من دجاج اللحم لمدة 21 يوماً ثم قسمت هذه الطيور إلى 3 مجموعات (معاملات) . تم تغذية كل مجموعة مستوى مختلف من حجم الذره (ناعم(94ملم)، متو سط (1.22ملم) وخشن(6 ملم)) و حيث إن كل معاملة مكررة 5 مرات بواقع 3 طيور لكل تكرار. تم ذبح الطيور في عمر 42 يوم وإزالة الأحشاء لدراسة تحليل وشكل القناة الهضمية للذبيحة. بينت النتائج أن حجم حبيبات الذرة لم تؤثر على معدل الزيادة الوزنية اليومية مع نهاية الأسبوع الرابع (تراوحت 73.57 – 75.18غم/ يوم)، الأسبوع الخامس (تراوحت 77.39–81.9 غم/يوم)، والأسبوع السادس(تراوحت 68.57–72.65غم/يوم)، كذللك لم تتأثر الكفاءة التحويلية مع نهاية الأسبوع الرابع (تراوحت 1.35 –1.55)، الأسبوع الخامس (تراوحت 1.62–1.87)، الأسبوع السادس (تراوحت 2.16–2.32). كذللك لم تتأثركمية العلف المأكول التراكمي مع نهاية الأسبوع الرابع (تراوحت 796–808 غم) والأسبوع الخامس (1007 تراوحت –1050 غم) والأسبوع السادس (تراوحت 1085.8–1159 غم). لم تؤثر حجم حبيبات الذرة على نسبة التصافي (تراوحت 73.9 –75.1 %) ووزن وطول أجزاء الجهاز الهضمي بالنسبة لوزن الجسم. الطيور التي تناولت ذرة متوسطة الحجم (1.22ملم) أظهرت انخفاض في الوزن والطول النسبي للقناة الهضمية (2.49غم/كغم وزن و 24.99سم/كغم وزن) مقارنة مع الطيور التي تناولت ذرة ناعمة (0,94ملم) (2.71غم/كغم وزن و 27.13سم/كغم وزن) والطيور التي تناولت ذرة خشنة (1,6 ملم) (2.78غم/كغم وزن و 27.82سم/كغم وزن). نستنتج أن طحن الذرة الخشنة فوق الأحجام الموصى بها لم يؤثر على نمو الطيور خلال مرحلة النمو في دجاج اللحم ولهذا يوصى باستخدام الأحجام الخشنة من الذرة في خلطات الدواجن.

الكلمات الدالة: حجم الحبيبات، كفاءة النمو، شكل القناة الهضمية، اللاحم.

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