



Original research article

Effects of feed form and feed particle size on growth performance, carcass characteristics and digestive tract development of broilers



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ABSTRACT

This study was conducted to evaluate the effects of feed form (mash and crumble-pellet) and feed particle size (fine, medium and coarse) on growth performance, carcass characteristics and digestive tract development of broilers. A total of 1,152 one day-old Ross 308 mixed-sex broilers were used in a factorial arrangement (2 × 3) based on a completely randomized design with six replicates of 32 birds each. Higher average daily gain (ADG) and average daily feed intake (ADFI) were observed ($P < 0.01$) for birds fed the crumble-pellet diets (CPD) than for those fed the mash diets (MD) during starter, grower and the entire experiment period. From d 1 to 40, birds fed CPD had a higher ($P < 0.01$) body weight (BW) than those fed MD. Birds fed CPD had a lower ($P < 0.01$) feed:gain ratio (F:G) during the starter phase than those fed MD. Medium or coarse particle size increased ($P < 0.01$) ADG and ADFI during the starter phase, but birds fed fine particle size diets had lower ($P < 0.01$) F:G during the grower phase. In MD, medium and coarse particle sizes resulted in higher ($P < 0.05$) BW, ADG and ADFI than fine particle size during the whole experiment. In CPD, particle size had no significant effect on growth performance, as indicated by a feed form × particle size interaction ($P < 0.05$). At 41 days of age, ten birds per treatment were randomly selected and killed for slaughter yields and digestive tract characteristics determination. It was shown that particle size and feed form alone had no significant effect on slaughter yields, so changes was the feed form × particle size interaction. The relative empty weight of the gizzard was greater ($P < 0.01$) and the relative length of the ileum was longer ($P < 0.05$) in birds fed MD than in those fed CPD. Overall, CPD improved growth performance during the entire period of the study with effects being less evident during the finisher phase than during the starter and grower phases, and the effect of feed particle size varied depending on feed form.

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1. Introduction

Physical feed form is considered to have a very significant impact on broiler growth and feed intake (Dozier et al., 2010). Feed form and feed particle size of cereals require a significant amount of attention when producing broiler feed. Today, commercial feed

mills are producing different forms of broiler feed for birds at different ages (Jahan et al., 2006). While feed processing to change feed form increases the cost of feed it can be balanced out by improved performance. Many researchers report that broilers fed pelleted diets have higher BW and improved feed conversion than those fed mash feed (McKinney and Teeter, 2004; Amerah et al., 2008; Chewning et al., 2012), and today pelleting has become a common processing method widely employed by the feed manufacturers to improve farm animal performance. Compared with mash, pellets enhance bird performance by decreasing feed wastage, alleviating selective feeding, destroying pathogens, improving palatability and increasing nutrient digestibility. One disadvantage is that pelleting costs about 10% more than producing mash feed (Jahan et al., 2006). With regards to feed particle size, one traditional view was that a smaller particle size would be

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associated with a larger surface area of the grain, possibly resulting in higher digestibility in poultry due to a greater interaction with digestive enzymes in the gastrointestinal tract (Preston et al., 2000). In more recent years, however, it is thought that a large particle size aided by some structural components is beneficial to gizzard functions and gut development (Hetland et al., 2002; Svihus et al., 2004; Choct, 2009).

The objective of this study was to investigate the effects of feed form (mash and crumble-pellet) and feed particle size (fine, medium and coarse) on broiler performance and development of the digestive tract.

2. Material and methods

The study was approved by the Animal Care and Experiment Committee of New Hope Liuhe Corporation. The experiment was divided into three phases, i.e., starter (d 1 to 21), grower (d 22 to 32) and finisher (d 33 to 40). A total of 1,152 one day-old Ross 308 mixed-sex broilers (1:1 ratio of males and females) were used in a completely randomized design with six treatments and six replicates of 32 birds each. They were arranged in a 2 × 3 factorial design: two feed forms (mash and crumble-pellet) and three feed particle sizes (fine, medium and coarse). The pelleting process was performed at a temperature of 75°C, and pellets were 4 mm in diameter. The pellets were crumbled in a roller mill, resulting in a crumbled diet. The 3 particle sizes were achieved by grinding the wheat, corn and soybean meal in the hammer mill to pass through 2-, 5- and 8-mm sieves, then particle size of the three ingredients was measured. The particle sizes for corn were 573, 865, 1,027 μm, for wheat 566, 1,110, 1,183 μm, and for soybean meal 490, 842, 880 μm, respectively. The particle size was determined by the method devised by the American Dairy Science Association (1970).

Birds on mash treatments were fed mash diets from d 1 to 40, whereas those on crumble-pellet diets were fed crumbles from d 1 to 21 and pellets from d 22 to 40. Corn and soybean meal-based diets (Table 1) were formulated to meet Ross 308 strain recommendations and differed only in particle size and feed form. Uniformity in the management practices was maintained as much as possible. The birds were housed in 200 × 180 cm floor pens with 4 nipples per pen. Initial room temperature was 34°C and was then decreased by 2°C per week until a temperature of 26°C was achieved. Feed and water were supplied *ad libitum*. All birds were immunized according to the routine immunization program, and the health and wellbeing of the birds was observed every day.

On d 1, 21, 32 and 40, chicks were weighed by pen and feed consumption was recorded. ADG, ADFI, F:G, and BW, including mortality weight, were calculated for each phase. On d 41, ten birds per treatment were randomly selected and weighed, then killed by exsanguinations after CO₂ stunning. After removal of feathers, feet and head, carcass yield was determined. Cut-up parts such as thigh, breast and abdominal fat were weighed. Meanwhile, proventriculus, gizzard, duodenum, jejunum and ileum were removed and the empty digestive tracts were weighed. In addition, the length of the small intestines was also measured.

All the data were analyzed by the GLM procedures of SAS 9.1. The statistical model included the effects of feed form (mash vs. crumble-pellet), feed particle size (fine, medium and coarse), and their interactions. Results were expressed as least squares means and standard error of the means (SEM). Duncan mean separation test was used to determine significant differences between treatment mean values ($P < 0.05$).

Table 1
Diet composition and nutrient levels (as-fed basis).

Items	d 1 to 21	d 22 to 32	d 33 to 40
Ingredients, %			
Corn	48.98	49.64	50.15
Wheat	10.00	15.00	20.00
Soybean oil	2.74	3.30	4.09
Soybean meal	34.57	28.73	22.77
Limestone	0.95	0.95	0.94
Dicalcium phosphate	1.88	1.50	1.12
Sodium chloride	0.31	0.31	0.31
L-Lysine	0.00	0.04	0.11
DL-methionine	0.17	0.13	0.11
Premix ¹	0.40	0.40	0.40
Total	100.00	100.00	100.00
Calculated analysis			
Crude protein, %	21.00	19.00	17.00
Calcium, %	0.90	0.80	0.70
AME, Kcal/kg	2,820	2,920	3,020
Lysine, %	1.00	0.90	0.80
Methionine + Cystine, %	0.76	0.68	0.61

¹ Supplied per kilogram of complete diet: Mg, 100 mg; Zn, 75 mg; Fe, 80 mg; I, 0.65 mg; Cu, 80 mg; Se, 0.35 mg; vitamin A, 9,000 IU (retinyl acetate); vitamin D₃, 2,000 IU (cholecalciferol); vitamin E, 11 IU (DL- α -tocopheryl acetate); vitamin K₂, 1.0 mg; vitamin B₁, 1.2 mg; vitamin B₂, 5.8 mg; niacin, 66 mg; pantothenic acid, 10 mg; vitamin B₆, 2.6 mg; biotin, 0.10 mg; folic acid, 0.7 mg; vitamin B₁₂, 0.012 mg.

3. Results

3.1. Growth performance

The effects of feed particle size and feed form on broiler performance are shown in Table 2. During the starter phase, medium or coarse particle size increased ($P < 0.01$) broiler ADG and ADFI significantly. Birds fed with crumble-pellet diets had better performance than those fed with mash diets ($P < 0.01$). Interaction for ADG and ADFI was significant ($P < 0.01$) between feed particle size and feed form. In the grower phase, birds fed the fine particle size diets had lower ($P < 0.01$) F:G than those fed medium or coarse particle size diets. Interaction for ADFI between feed particle size and feed form was significant ($P < 0.05$). No significant effect for performance was observed in the finisher phase ($P > 0.05$). During the whole period, particle size had no significant effect on broiler performance ($P > 0.05$), while birds fed with crumble-pellet diets had higher BW, ADFI and ADG than those fed with mash diets ($P < 0.01$). The interaction between feed particle size and feed form was significant for BW, ADFI and ADG. The survival rate did not differ significantly between crumble-pellet and mash fed birds, nor between different particle size treatments.

3.2. Carcass characteristics and digestive tracts development

There was no remarkable difference for carcass yield values (Table 3) among all treatments and yields ranged from 74.2 to 75.9%. Similarly, other carcass traits such as breast, thigh and abdominal fat relative weight showed little variation ($P > 0.05$). No feed particle size × feed form interaction for carcass traits was observed in this study.

Among the relative empty weight of digestive tracts, the gizzard weights of crumble-pellet fed birds were significantly ($P < 0.05$) lower than mash fed birds measured on day 41 (Table 4). Further to that, the ileum weight decreased progressively with feed particle size, and the ileum length differed between birds fed crumble-pellet and mash diets. No feed

Table 2
Effects of feed particle size and feed form on growth performance of broiler in each and whole period.¹

Item	Starter (d 1 to 21)			Grower (d 22 to 32)			Finisher (d 33 to 40)			Whole period (d 1 to 40)				
	ADG, g/d	F:G	ADFI, g/d	ADG, g/d	F:G	ADFI, g/d	ADG, g/d	F:G	ADFI, g/d	BW, g	ADG, g/d	F:G	ADFI, g/d	Survival rate, %
Crumble-pellet														
Fine	40.9 ^a	1.361 ^{ab}	55.6 ^a	90.8 ^a	1.678 ^c	152.3 ^a	86.5	2.055	177.6	2550 ^a	63.8 ^a	1.672	106.6 ^a	96.9
Medium	40.9 ^a	1.346 ^b	55.0 ^a	87.9 ^a	1.707 ^{abc}	149.8 ^a	86.6	2.037	175.9	2520 ^a	63.0 ^a	1.672	105.3 ^a	96.4
Coarse	40.9 ^a	1.360 ^{ab}	55.7 ^a	88.1 ^a	1.727 ^a	152.0 ^a	84.6	2.011	169.2	2505 ^a	62.6 ^a	1.675	104.9 ^a	97.4
Mash														
Fine	36.4 ^c	1.384 ^a	50.3 ^c	79.7 ^b	1.683 ^{bc}	134.0 ^c	82.3	2.023	166.4	2298 ^c	57.5 ^c	99.0	96.5 ^c	99.0
Medium	38.9 ^b	1.372 ^{ab}	53.4 ^b	81.8 ^b	1.717 ^{ab}	140.4 ^b	84.4	2.015	170.0	2396 ^b	59.9 ^b	1.680	100.6 ^b	97.9
Coarse	38.6 ^b	1.386 ^a	53.4 ^b	81.5 ^b	1.746 ^a	142.3 ^b	88.4	1.969	173.9	2415 ^b	60.4 ^b	1.689	102.0 ^b	99.0
Pooled SEM	0.3	0.004	0.34	0.84	0.006	1.32	0.98	0.01	1.3	18.71	0.47	0.003	0.69	0.44
Main effect														
<i>Particle size</i>														
Fine	38.6 ^b	1.372	53.0 ^b	85.2	1.680 ^b	143.2	84.4	2.039	172.0	2424	60.6	1.676	101.6	97.9
Medium	39.9 ^a	1.359	54.2 ^a	84.8	1.712 ^a	145.1	85.5	2.026	172.9	2458	61.5	1.676	102.9	97.1
Coarse	39.7 ^a	1.373	54.5 ^a	84.8	1.736 ^a	147.1	86.5	1.99	171.5	2460	61.5	1.682	103.4	98.2
<i>Feed form</i>														
Crumble-pellet	40.9 ^a	1.356 ^b	55.4 ^a	88.9 ^a	1.704	151.4 ^a	85.9	2.034	174.2	2525 ^a	63.1 ^a	1.673	105.6 ^a	96.9
Mash	37.9 ^b	1.380 ^a	52.4 ^b	81.0 ^b	1.715	138.9 ^b	85.0	2.002	170.1	2370 ^b	59.2 ^b	1.683	99.7 ^b	98.6
Probability														
Particle size	**	NS	**	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
Feed form	**	**	**	**	NS	**	NS	NS	NS	**	**	NS	**	NS ²
Particle size × Feed form	**	NS	**	NS	NS	*	NS	NS	*	*	*	NS	**	NS

^{a-c}Means in the a column not sharing a common online are different ($P < 0.05$).

NS = Not significant, * $P < 0.05$, ** $P < 0.01$.

ADG = average daily gain; ADFI = average daily feed intake; BW = body weight; F:G = feed:gain; SEM = standard error of the means.

¹ Average initial BW of 40.8 g.

² $P = 0.06$.

Table 3
Effects of feed particle size and feed form on carcass traits of broiler at 41 days of age.^{1,2}

Item	Carcass yield	Breast	Thigh	Abdominal fat
Crumble-pellet				
Fine	75.89	19.44	24.91	2.28
Medium	75.33	19.04	24.86	2.11
Coarse	75.02	18.98	24.69	2.41
Mash				
Fine	75.25	18.63	25.11	2.07
Medium	74.19	19.02	23.79	2.08
Coarse	75.04	19.24	24.40	2.20
Pooled SEM	0.19	0.17	0.14	0.05
Probability				
Particle size	NS	NS	NS	NS
Feed form	NS	NS	NS	NS
Particle size × Feed form	NS	NS	NS	NS

NS = Not significant; SEM = standard error of the means.

¹ Each value represents the mean of 10 birds (male).

² % of live bird weight.

particle size × feed form interaction for digestive tracts was observed.

4. Discussion

4.1. Growth performance

Galobart and Morant (2005) and Salari et al. (2006) reported that the form of diet and particle size had no significant effect on weight gain and dry matter intake. However, results of this experiment indicated that feed form and particle size both affected

weight gain and intake. Numerically, feed form had a greater impact on the growth performance than particle size. A fine (2 mm) mash diet resulted in lower ADG and ADFI than other (5 or 8 mm) mash during the starter phase, also affecting the F:G during grower phase. But pelleting masked the effects of different particle sizes in the present study. These results were similar to those reported by Amerah et al. (2007) and Aderibigbe et al. (2013). Partial differences in the results between those studies may be due to different opening sizes of screens used. However, results showed that particle size had no remarkable effects on growth performance in crumble-pellet diets. It indicated that particle size was more critical for performance in birds fed mash diets than those fed crumble-pellet diets, which is supported by the finding of Svihus et al. (2004), concluded that pelleting evened out the differences in particle size distribution.

It is commonly accepted that pelleted poultry rations increase weight gain and improve feed efficiency. For instance, pelleting complete diets improved weight gain, feed conversion and feed intake in broilers (Zang et al., 2009). Kim et al. (1996) concluded that crumble-pellet treatment significantly improved feed conversion. Mirghelenj and Golian (2009) also found feeding crumble-pelleted diets caused a significant increase in feed intake. No F:G response was observed during the entire period in the current study. The advantage of the crumble-pellet diets may result from an increase in appetite and diet density, a decrease in feed wastage, and alterations in ingredients (Jensen et al., 2000). In the current study, crumble-pellet feed increased feed intake by 5 to 8% during starter and grower phases, respectively, compared with mash diets. Similar results were found by Jahan et al. (2006), who reported that birds had greater feed intake with crumble or pellets than mash feeding. This may be associated with better growth performance when birds are fed pelleted diets (Mirghelenj and Golian, 2009).

Table 4
Effects of feed particle size and feed form on the weight and length of digestive tract of broilers at 41 days of age.¹

Item	Relative empty weight, g/100 g of BW					Relative length, cm/kg of BW		
	Proventriculus	Gizzard	Duodenum	Jejunum	Ileum	Duodenum	Jejunum	Ileum
Main effect								
Particle size								
Fine	0.307	1.05	0.51	0.91	0.72 ^a	11.1	28.9	28.4
Medium	0.315	1.09	0.53	0.90	0.67 ^{ab}	11.9	29.7	28.7
Coarse	0.314	1.16	0.50	0.88	0.60 ^b	11.3	29.4	27.3
Feed form								
Crumble-pellet	0.316	1.02 ^b	0.51	0.90	0.66	11.3	29.5	27.1 ^b
Mash	0.307	1.18 ^a	0.52	0.89	0.67	11.6	29.2	29.2 ^a
Probability								
Particle size	NS	NS	NS	NS	*	NS	NS	NS
Feed form	NS	**	NS	NS	NS	NS	NS	*
Particle size × Feed form	NS	NS	NS	NS	NS	NS	NS	NS

^{a,b}Means in the same column not sharing a common online are different ($P < 0.05$).

NS: Not significant, * $P < 0.05$, ** $P < 0.01$.

BW = body weight; SEM = standard error of the means.

¹ Each value represents the mean of 10 birds (male).

4.2. Carcass characteristics and digestive tracts development

In this study, carcass evaluation results showed that feed forms and feed particle sizes alone produced no significant difference in the carcass yield and carcass traits. This supported the findings of Ebrahimi et al. (2010) and Sogunle et al. (2013), who reported that feed forms and feed particle size had no effect on the dressing percentage, so effects were found in the interaction of feed forms and particle sizes.

Promotion of gizzard development is one nutritional strategy, which can be achieved by manipulating feed particle size. A positive relationship between gizzard weight and particle size was reported by Nir et al. (1994). While in this study, no significant difference ($P = 0.09$) with regards to particle size effect on gizzard development was observed in different treatments, which may be caused by opening sizes of screens and the species of poultry used.

This study also showed that mash diets improved birds gizzard development better than crumble-pellet diet fed birds. Similar results and conclusions about the effect of feed form on gizzard development were observed by Svihus et al. (2004). Remarkable gizzard relative weight reduction was observed when broiler mash diets were replaced by whole wheat diets or pelleted diets. The reduction of gizzard weight could be attributable to the lack of mechanical stimulation by the feed. Pelleting reduced feed particle size, and small particles are retained in the gizzard for less time than coarse particles, resulting in less mechanical stimulation (Mateos et al., 2012) and reduced organ size (Svihus, 2011).

In addition, the study showed that broilers fed mash diets had significantly larger relative ileum length compared to birds fed pelleted diets, which is similar to the finding of Chewning et al. (2012).

5. Conclusions

Feed form had a greater effect on broiler growth performance and digestive tracts than feed particle size. Feeding crumble-pellet diets improved bird performance, which may be due to higher feed intake and lower feed wastage. Moreover, the effect of feed particle size varied depending on feed form.

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