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Effects of Starter Diet Feed Particle and Crumble Size on Performance, Carcass Characteristics and Small Intestinal Histomorphology in Broiler Chicks

Research Article

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ABSTRACT

This study was conducted to assess the effects of feed particle size (FPZ) and crumble size (CZ) of starter diet on growth performance parameters, carcass characteristics, and small intestinal histomorphology in broiler chicks. Three hundred and sixty male Ross 308 chicks were randomly distributed in a completely randomized design with 3 × 2 factorial arrangement consist of three screened FPZs (500, 1000 and 1500 µm) and two CZs (1.5 and 2.5 mm). Each treatment included six replicates (10 broiler chicks per cage) and chicks were reared in the cage from 0-10 d of age. The results indicate that neither main factors nor interaction between FPZ and CZ had any significant effect on body weight (BW) and European production efficiency factor (EPEF) at 10 d. However, a significant interaction effect ($P<0.05$) between FPZ and CZ were observed for feed intake (FI), feed conversion ratio (FCR) and feed efficiency (FE). FPZ had a significant effect ($P<0.05$) on gizzard relative weight. Increasing FPZ significantly ($P<0.05$) increased gizzard relative weight. Both FPZ of 1500 µm and CZ of 2.5 mm numerically caused FI reduction, improved FCR, FE, increased EEPF and reduced abdominal fat weight. The CZ had significant ($P<0.05$) effect on relative gizzard muscular thickness. As the CZ increased, the relative gizzard muscular thickness significantly ($P<0.05$) decreased. The effect of CZ on villous high (VH) of ileum was significant ($P<0.05$). Indeed, as the CZ increased, the VH of Ileum significantly decreased ($P<0.05$). A significant interaction ($P<0.05$) between FPZ and CZ was seen in FI, FCR, FE, gizzard relative weight and relative gizzard muscular thickness, absolute fat weight of gizzard. In the diet made from the FPZ of 1500 µm and CZ of 1.5 mm FI significantly ($P<0.05$) reduced, FE and FCR significantly ($P<0.05$) improved. In conclusion, birds fed coarsely FPZ (1500 µm) and smaller CZ (1.5 mm) diet showed better FCR and FE which was due to enhanced gizzard development and intestinal histomorphology parameters.

KEY WORDS broiler, crumble size, feed particle size, gizzard, performance.

INTRODUCTION

Historically, feed particle size reduction endured the main paradigm of feed manufacturing (Xu *et al.* 2015a). As a traditional view smaller feed particle size would be 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 (Goodband *et al.* 2002). However, poultry nutritionists recently preferred coarsely ground cereals since they found that a minimal level of structural component in the diet must exist for preventing gizzard dystrophy, which is acts as the pacemaker of gut motility (Svihus, 2011).

The results of the previous study revealed that the feed physical form (mash, pellet or crumble) impact was greater than feed particle size on poultry performance (Engberg *et al*. 2002; Shabani *et al*. 2015). Lv *et al*. (2015) report that broilers fed crumble diets had significant better FCR in comparison to mash diet during starter period (0-21 d). Moreover, Xu *et al*. (2015c) illustrated that broiler fed crumble diets had significantly higher FI and BW than mash diet during starter period (0-7 d). Amerah *et al*. (2007a) and Amerah *et al*. (2007c) concluded that feed particle size was more critical in mash diet than pellet or crumble diets. Therefore, a better comprehension of the interaction between feed particle size and upper gut development and function has became crucial to optimization of feed manufacturing strategies and broiler performance. Naderinejad *et al*. (2016) indicted that coarse corn grinding is beneficial to growth performance in broilers fed starter pellet diets (0-21 d). Hence, there is a lack of information about the impact of feed particle size in broilers crumble diets. Moreover, the effects of feed particle and crumble size on intestinal morphology have not been evaluated and merit further investigation. The object of the current study was to find an optimum feed particle and crumble size of broiler starter diet.

MATERIALS AND METHODS

Feed formulation, manufacture and experiment design

Broiler corn-soybean meal diets were formulated to meet suggested requirement (Aviagen, 2014) and manufactured in the Karun feed mill co., Khosestan, Iran (Table 1). Corn and soybean meal were ground separately by hammer mill (16 hammers). Then, they were screened by specific standard sieve aperture size of 500, 1000 and 1500 µm and theses feed particles were separated in order to produce each of six diets.

The mash feeds were conditioned in a single barrel conditioner (75 ˚C discharge feed temperature, 30 sec retention time) and then, they were pelleted by a pellet press machine equipment with a ring die (4×40 mm diameter:length). Pellets were cooled with ambient air in a counter-flow cooler and then crumbled in order to produce two crumble sizes of 1.5 and 2.5 mm. Finally, crumble dust and fine particle were removed by rotary-sieve grader.

Husbandry practices

A total of 360 male Ross 308 chicks were placed in environmentally controlled room of Islamic Azad University of Izeh branch poultry farm. Broilers were reared in 36 cages (10 male birds in each).

Temperate and light program were settled based on Ross 308 strain guideline 2014. Feed and water were available for *ad libitum* consumption. The vaccination program was done according to local veterinarian suggestion.

Table 1 Feed ingredients and chemical composition of the starter diet (%)

Ingredients	**(%)**
Corn	39.81
Soybean-meal (44%)	33.75
Vegetable oil	2.15
Wheat	10.5
Wheat flour	7.5
Starch	1
Di-calcium phosphate	1.77
Calcium carbonate	1.09
Sodium bicarbonate	0.14
Sodium chloride	0.18
Vitamin premix[1]	0.25
Mineral premix[2]	0.25
L-lysine-HCl	0.14
DL-methionine	0.25
L-threonine	0.1
Feed additives[3]	1.12
Calculated values	
Metabolisable energy kcal/kg	2962
Crude protein (%)	21
Digestible amino acid lysine (%)	1.27
Digestible amino acid methionine + cysteine (%)	0.81
Digestible amino acid threonine (%)	0.76
Calcium (%)	0.9
Available phosphorus (%)	0.45

[1] Supplied per kg diet: vitamin A: 9000 IU; vitamin D_3: 2000 IU; vitamin E: 18 IU; vitamin K_3: 2 mg; vitamin B_1: 1.8 mg; vitamin B_2: 6.6 mg; vitamin B_3: 10 mg; vitamin B_5: 30 mg; vitamin B_6: 3 mg; vitamin B_9: 1 mg; vitamin B_8: 0.1 mg; vitamin B_{12}: 0.015 mg; Choline: 250 mg and Antioxidant: 100 mg.

[2] Supplied per kg diet: Mn: 99.2 mg; Fe: 50 mg; Zn: 84.7 mg; Cu: 10 mg; I: 1 mg; Se: 0.2 mg and Choline: 250 mg.

[3] Feed additive consists of: Zeolite: 1%; Mold inhibitors: 0.05%; Biozyme™: 0.05% enzyme and Probiotic: 0.02.

Data collection

Initial cage group body weight were collected at placement. Feed intake and body weight by cage were recorded from 1-10 d of age. Feed conversion ratio, feed efficiency and European production efficiency factor were calculated for starter period.

At 10 d of age, one bird from each replicate was selected, individually weighted, euthanized by chloroform and killed by cervical dislocated then inner organs were excised and samples were collected. The fat surrounding abdominal, gizzard and heart were trimmed, the gizzard content was removed, then absolute weight of these organs fat was recorded and expressed as percentage of BW (g/g). Relative gizzard muscular thicknesses was measured by calipers and expressed as mm of muscular thicknesses of BW (Svihus, 2011).

Intestinal histomorphology

Sections from middle of duodenum, jejunum and ileum (about 2 cm in length) were excised on 10 d of age and flushed with PBS and samples were placed in formalin 10% fluid. Samples were dehydrated through graded level of alcohols then embedded in wax and cut using microtome using feather S35 disposable blades at a sickness of 7 µm. Samples were stained with hematoxyline-eosin and intestinal hisotomorphology parameters such as villus height (VH), crept depth (CD) and villus thickness (VT) examined by light microscope equipped with an eyepiece graticule.

Statistical analysis

Data were analyzed as completely randomized design with 3 × 2 factorial arrangement to determine the main effects and interactions of three feed particle sizes (500, 1000, 1500 µm) and two crumble sizes (1.5 and 2.5 mm). All data were analyzed using general linear model (PROC GLM) of SAS program (SAS, 2009). Mean differences were considered significant at $P < 0.05$ by using Duncan's multiple-range test (Kaps and Lamberson, 2009).

RESULTS AND DISCUSSION

Growth performance parameters

The effects of feed particle and crumble size on growth performance parameters of starter period were shown in Table 2. Neither the main factors nor the interaction between feed particle and crumble size had any significant ($P>0.05$) effects on BW and EPEF.

A significant interaction ($P<0.05$) between feed particle and crumble size for FI, FCR and FE at 10 d was observed. Inspection of interactions revealed that the crumble diets contained 1500 µm feed particle size plus crumble size of 1.5 mm and 1000 µm feed particle size plus 2.5 mm crumble size had the significant differences for FI, FCR and FE ($P<0.05$) in comparison to 500 µm feed particle size plus 1.5 mm crumble size.

Carcass characteristics

The effects of feed particle and crumble size on liver, heart and gizzard relative weight, gizzard muscular thicknesses and absolute fat weight of abdominal, gizzard and heart at 10 d were illustrated in Tables 3 and 4. The main factors and the interaction between feed particle and crumble size had no significant ($P>0.05$) effects on liver and heart relative weight, abdominal and heart fat absolute weight. Feed particle size and crumble size had a significant effect ($P<0.05$) on relative gizzard weight and muscular thicknesses, respectively. As the feed particle size became larger, the gizzard relative weight was significantly ($P<0.05$) increased. Increasing crumble size were significantly ($P<0.05$) reduced relative gizzard muscular thickness. The interaction between feed particle and crumble size was observed for absolute fat weight of gizzard ($P<0.05$). Indeed, birds fed the diets made from 1500 µm feed particle size plus crumble size of 1.5 mm, 1000 µm feed particle size plus 2.5 mm crumble size and 500 µm feed particle size plus 2.5 mm crumble size had significant differences for abdominal absolute fat weight ($P<0.05$) in comparison to 1500 µm feed particle size plus 2.5 mm crumble size diet.

Intestinal histomorphology

The impact of feed particle and crumble size on VH, CD and VT of duodenum, jejunum and ileum were illustrated in Table 5. Although, feed particle size had no significant impact on intestinal histomorphologic parameters, the effect of crumble size on VH of jejunum and VT of ileum was tended to be significant at $P= 0.07$ and $P= 0.06$, respectively. The effect of crumble size on VH of ileum was significant ($P<0.05$). In fact, as the crumble size was increased, the VH of Ileum was significantly decreased ($P<0.05$).

Growth performance parameters

It can be said that neither main factors nor interaction between feed particle and crumble size had any significant effect on BW and EPEF, but significant interaction ($P<0.05$) were observed for FI, FCR and FE in the starter period. In fact, diets made from 1500 µm feed particle size plus crumble size of 1.5 mm and 1000 µm feed particle size plus 2.5 mm crumble size had the significant differences for FI, FCR and FE ($P<0.05$) in comparison to 500 µm feed particle size plus 1.5 mm crumble size. The best growth performance results, specifically on FCR and FE among other treatments were achieved by the diet made from large feed particle size (1500 µm) plus smaller crumble size (1.5) and medium feed particle size (1000 µm) plus larger crumble size (2.5 mm). In fact, better gizzard development and probably better nutrient digestibility through the large or medium feed particle size lead to increasing better feed efficiency and better feed conversion ratio in these treatments (Zaefarian *et al.* 2016). However, the lower feed intake in these treatments may related to longer digesta retention time in the gizzard (Svihus, 2011). Increasing feed particle size and crumble size numerically decreased FI, improved FCR, FE and EPEF. The results of previous studies on pellet diets with different feed particle size revealed that FI decreased and FCR improved when broiler fed coarser in comparison to finer feed particle size (Amerah *et al.* 2007b; Amerah *et al.* 2008). FI reduction was probably related to greater digesta grinding and retention time to make suitable particle size before exiting the gizzard (Svihus, 2011).

Table 2 Effects of feed particle and crumble size on performance parameters during the starter period

Parameters	Growth performance parameters (0-10 d)				
	BW (g)	FI (g)	FE (%)	FCR (g/g)	EEPF (%)
Feed particle size (μm)					
500	236	303	78	1.28	184
1000	236	287	82	1.21	195
1500	235	283	83	1.20	196
SEM	4.46	5.35	1.89	0.03	6.90
Crumble size (mm)					
1.5	237	295	80	1.24	191
2.5	234	287	82	1.22	192
SEM	3.64	4.37	1.54	0.02	5.64
Interaction					
500×1.5	238	314^{a}	76^{b}	1.32^{a}	180
500×2.5	234	292^{ab}	80^{ab}	1.25^{ab}	188
1000×1.5	235	294^{ab}	80^{ab}	1.25^{ab}	188
1000×2.5	237	280^{b}	85^{a}	1.18^{b}	203
1500×1.5	238	277^{b}	86^{a}	1.16^{b}	206
1500×2.5	231	289^{ab}	80^{ab}	1.25^{ab}	185
SEM	2.58	3.09	1.09	0.01	3.99
P-value					
Feed particle size	0.97	0.12	0.15	0.11	0.42
Crumble size	0.64	0.32	0.60	0.41	0.90
Interaction	0.76	0.05	0.05	0.05	0.17

BW: body weight; FI: feed intake; FE: feed efficiency; FCR: feed conversion ratio; EEPF: European production efficiency factor.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 3 Effects of feed particle and crumble size on relative weight of inner organs and gizzard muscular thicknesses and at day 10

Parameters	Relative weight (g/BW)			Relative gizzard muscular thicknesses (mm/BW)
	Liver	Heart	Gizzard	
Feed particle size (μm)				
500	4.61	0.81	2.77^{b}	4.40
1000	4.88	0.84	3.19^{ab}	4.58
1500	4.81	0.75	3.51^{a}	3.70
SEM	0.44	0.08	0.21	0.28
Crumble size (mm)				
1.5	4.72	0.82	3.08	4.56^{a}
2.5	4.80	0.77	3.23	3.89^{b}
SEM	0.36	0.05	0.17	0.23
Interaction				
500×1.5	4.65	0.76	2.53	4.45
500×2.5	4.57	0.85	3.01	4.34
1000×1.5	5.35	0.91	3.15	5.43
1000×2.5	4.51	0.76	3.22	3.73
1500×1.5	4.30	0.79	3.55	3.80
1500×2.5	5.32	0.72	3.47	3.59
SEM	0.25	0.03	0.12	0.16
P-value				
Feed particle size	0.88	0.59	0.05	0.08
Crumble size	0.95	0.50	0.51	0.05
Interaction	0.35	0.36	0.61	0.10

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 4 Effects of feed particle and crumble size on absolute fat weight of abdominal, gizzard and heart at day 10

Parameters	Absolute fat weight (g)		
	Abdominal	**Gizzard**	**Heart**
Feed particle size (µm)			
500	1.81	1.01	0.30
1000	1.72	1.03	0.29
1500	1.67	1.07	0.23
SEM	0.15	0.08	0.03
Crumble size (mm)			
1.5	1.86	0.98	0.26
2.5	1.61	1.10	0.29
SEM	0.12	0.07	0.02
Interaction			
500×1.5	2.11	1.05^{ab}	0.30
500×2.5	1.52	0.96^{b}	0.30
1000×1.5	1.85	1.08^{ab}	0.27
1000×2.5	1.60	0.99^{b}	0.30
1500×1.5	1.62	0.79^{b}	0.22
1500×2.5	1.72	1.35^{a}	0.25
SEM	0.08	0.05	0.02
P-value			
Feed particle size	0.79	0.87	0.18
Crumble size	0.15	0.22	0.45
Interaction	0.26	0.02	0.90

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 5 Effects of feed particle and crumble size on intestinal hisotomorphologic parameters

Parameters	Duodenum (µm)			Jejunum (µm)			Ileum (µm)		
	VH	**VT**	**CD**	**VH**	**VT**	**CD**	**VH**	**VT**	**CD**
Feed particle size (µm)									
500	804	163	191	711	150	159	494	112	182
1000	762	145	194	638	136	182	502	108	137
1500	854	168	196	724	150	219	475	103	130
SEM	44	11	10	50	8.6	24	32	7.7	21
Crumble size (mm)									
1.5	812	152	187	745	147	173	538^{a}	118	149
2.5	801	165	201	638	143	200	443^{b}	98	150
SEM	36	9.1	8.4	41	7.0	19.5	26	7.2	17
Interaction									
500×1.5	847	159	202	797	159	159	545	124	151
500×2.5	762	166	182	626	140	159	442	99	214
1000×1.5	759	128	185	662	126	171	549	115	148
1000×2.5	765	161	204	615	145	193	455	101	126
1500×1.5	831	168	175	776	154	189	518	114	149
1500×2.5	877	169	218	671	145	249	432	93	111
SEM	25	6.4	6.0	29	4.9	14	19	5.1	13
P-value									
Feed particle size	0.35	0.30	0.95	0.44	0.43	0.23	0.84	0.79	0.20
Crumble size	0.83	0.31	0.25	0.07	0.75	0.34	0.02	0.06	0.98
Interaction	0.57	0.57	0.16	0.68	0.26	0.67	0.98	0.90	0.23

VH: villous height; VT: villous thicknes thickness and CD: crept depth.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

It seems that FCR and FE improvement was probably related to increasing gizzard activity caused by coarser feed particle size (Xu *et al.* 2015b).

Apparently, young broilers, had a limitation in consuming large crumble size (2.5 mm).

These data were consistent with Nir and Pitch (2001) statement that bird select feed material bases on particle size in other words crumble size. Apparently, preference for crumble size was related to beak dimensions and vary with age.

Carcass characteristics

Not only feed particle but also crumble size had no significant impact on liver and heart relative weight and absolute fat weight of abdominal, gizzard and heart at 10 d. Feed particle size had a significant effect (P<0.05) on gizzard relative weight. By increasing feed particle size, the gizzard relative weight was significantly (P<0.05) increased. These data supported that coarser feed particle size was able to stimulate gizzard development even in crumble diets. Likewise, in pellet diets study, similar results were observed on relative weight of gizzard (Naderinejad *et al.* 2016). In contrast, Xu *et al.* (2015c) reported that coarse feed particle had no impact on relative weight of gizzard in crumble diets in comparison to mash diets. It seems that positive impact of coarse particles may still exist after pelleting and crumbling. Gizzard acts as the pacemaker of gut motility (Svihus, 2011). In fact, a well-developed gizzard led to stronger reverse peristalsis contractions with overall result of improved nutrient utilization (Zaefarian *et al.* 2016).

These data revealed that larger crumble size were significantly (P<0.05) reduced relative gizzard muscular thickness (mm/BW). However, Svihus (2011) and Svihus (2014) mentioned that higher grinding activity increases the size of the gizzard muscles.

Broilers fed the diets consist of 1500 µm feed particle size plus crumble size of 1.5 mm, 1000 µm feed particle size plus 2.5 mm crumble size and 500 µm feed particle size plus 2.5 mm crumble size had significant differences in abdominal absolute fat weight (P<0.05) in comparison to 1500 µm feed particle size plus 2.5 mm crumble size diet.

Intestinal histomorphology

The effect of feed particle size on intestinal histomorphologic parameters was not significant, but the effect of crumble size on VH of jejunum and VT of ileum was tended to be significant. The results revealed that as the crumble size was increased, the VH of Ileum was significantly decreased (P<0.05).

Pellet and crumble diets disintegrated rapidly in upper gut sections and pass directly through gizzard to duodenum (Zaefarian *et al.* 2016). Therefore, it seems higher load of nutrient in digesta of jejunum and ileum by feeding small crumble size diet was probably lead to higher VH of these sections.

CONCLUSION

In order to enhance the performance, an optimum functionality of gastro-intestinal tract in broilers is crucial. Although feed particle and crumble size had no significant effect on BW at 10 d, an interaction between feed particle and crumble size was observed for FCR and FE. It seems that positive impact of coarse particles may still exist after crumbling. In conclusion, chicks fed the diets consist of coarsely feed particle size (1500 µm) and smaller crumble size (1.5 mm) showed better FCR and FE which was due to enhanced gizzard development and intestinal histomorphologic parameters.

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