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Evaluation of Crumble and Pellet Quality on Broiler Performance and Gizzard Weight

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Abstract: A 14 days cage study followed by a 35 days floor pen study investigated the effect of percentage fines in crumbles and percentage pellets, respectively on broiler performance. The cage study was a 2×6 factorial of sex and feed forms (mash, 0, 25, 50, 75 and 100% crumbles). There were 10 birds in each of the 8 replicated cages for each of the 12 interactions. Birds were fed corn-soy starter diets in either mash or crumble form. Nine birds per cage were thereafter moved to floor pens at 15 days of age and fed grower and finisher diets comprised of either 50 or 100% pellets. BW and feed consumption were determined at 7, 14, 28, 35, 42 and 49 days of age and Adjusted Feed Conversion Ratio (AdjFCR) was calculated by including the BW of dead birds. Gizzard weight and BW were obtained from one bird per pen at 14 and 49 days of age. The actual percentage crumbles in the 0, 25, 50, 75 and 100% starter diets was 9, 39, 53, 75 and 93%, respectively. The percentage pellets in the 50 and 100% pelleted grower and finisher diets was 46 and 97% and 51 and 81%, respectively. The 14 days BW of the birds fed the crumbles was greater than those fed mash (mean 488 versus 421 g) and the BW of the chicks increased linearly as the percentage crumbles increased. The greater BW observed due to crumble quality at 14 days in the cages disappeared by 35 days in the floor pens. Birds fed 100% pellets were heavier (3,602 g) than 50% pellets (3,424 g) at 49 days with improved AdjFCR (2.02 versus 2.08) from 15-49 days. The relative gizzard weight of birds fed 50% pellets was greater (0.43 versus 0.35 g/100 g BW) at 49 days of age. The results of these studies indicated that differences in BW due to percentage crumbles in the starter feed was not evident after 28 days while the greater percentage pellets in the grower and finisher feeds produced a greater BW and improved AdjFCR.

Key words: Crumbles, pellet, feed form, broiler, gizzard, USA

INTRODUCTION

The increased world demand for cereal grain and soybean meal protein coupled with increased biofuel production in the United States has resulted in higher feed costs for the broiler industry. Increased feed costs have resulted in higher overall production costs. The literature contains extensive information on the nutritional requirements of birds but there have been a limited number of studies that have evaluated the effect of feed manufacturing on broiler performance. The potential impact that feed manufacturing can have on the feed efficiency of broilers has become increasingly important as the price of ingredients and feed has increased.

The broiler industry has typically fed crumbled feed up to approximately 15 days of age. Crumbles have typically been produced from pellets that were passed through a set of crumble rolls at a specific gap width. The gap width between the two rolls must be adjusted to effectively reduce the pellets to crumbles with a minimal amount of fines in order to produce a uniform crumble quality (Wilson *et al*., 2001). Birds fed a crumbled starter diet have been reported to gain more BW and consume more feed as compared to birds presented feed in mash form (Choi *et al*., 1986). A study conducted by Wilson *et al*. (2001) investigated the relationship between crumble size and growth performance in broiler chicks and observed no differences in BW gain between coarse crumbles (>4.0 mm) and medium crumbles (1.5-4 mm) but fine crumbles (<1.5 mm) resulted in lower BW gain (777, 776 and 738 g, respectively). A similar result was observed for Feed Conversion Ratio (FCR) (1.34, 1.32 and 1.38) at 21 days of age. However, research on the impact that the percentage fines in a crumbled diet has on chick performance has remained limited.

Research has shown that broilers fed high quality pellets grew 2.7% faster as compared to birds fed diets that contained low quality pellets with the improved growth attributed to increased feed consumption of the grower and finisher diets (Dozier *et al*., 2010).

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Svihusa *et al*. (2004) also reported a 25% increase in feed intake and BW gain when broilers were fed pelleted diets as compared with mash diets. Behnke suggested that broilers fed pellets had improved performance due to increased digestibility of the feed decreased ingredient segregation, reduction of energy expended during feeding and increased palatability.

The form of the diet and amount of fines may also affect gizzard development. A well-developed gizzard can modulate gut motility in a favorable manner (Ferket, 2000) and may inhibit the growth of pathogenic bacteria in the small intestine (Bjerrum *et al*., 2005) thus diminishing the risk of coccidiosis and other enteric diseases (Cumming, 1994; Engberg *et al*., 2002; Bjerrum *et al*., 2005; Amerah *et al*., 2007). Choi *et al*. (1986) reported that feeding crumbles as compared to mash during the starter period significantly decreased gizzard weight at 4 weeks of age. The relative weight of the gizzard was also reduced in broilers fed pelleted feed as compared to birds consuming feed in mash form (Amerah *et al*., 2007). The objective of the present study was to determine if percentage fines in crumbled and pelleted feeds affected broiler performance and gizzard development and if the response differed in male and female broilers.

MATERIALS AND METHODS

Corn-soy diets were formulated and manufactured for starter, grower and finisher feeds (Table 1) that met or exceeded the NRC (1994) suggested minimum requirements of broilers. A basal diet was manufactured for the mash treatment and five crumble treatments (0, 25, 50, 75 and 100%) for the initial 14 days cage study. The grower and finisher treatments of 50 and 100% pellets were produced by pelleting and removing the fines (100%) from the pellets after cooling and then recombining the fines with screened pellets to create the 50% treatment. To equalize nutrient intake among pens, the broilers were fed 0.56 kg/bird of starter, 2.66 kg/bird of grower and 3.38 kg/bird of finisher diet.

The crumbled and pelleted diets were pelleted at 85°C using a 4.4 mm by 35 mm die (California Pellet Mill, Crawfordsville, In). A crumble/pellet scalper was used to remove the fines from the crumbles and pellets. The treatment diets were produced by blending the removed fines with the crumbles and pellets in a double ribbon mixer in order to precisely create the experimental treatments. The percentage of crumbles and pellets was determined by probing bags of finished feed and screening the samples.

The care of the birds used in the study conformed to the Guide for Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999). A total of 960 Ross 344×708 broiler chicks were placed on the day of hatching in four Petersime batteries with electrical brooders and wire mesh floors. Two environmentally controlled rooms with eight battery cages were used. Each battery had 12 cages distributed over 6 decks. Ten birds were placed per cage with 96 cages in total. Each cage was randomly assigned to 1 of 12 treatments with a total of 8 pens assigned to each treatment. Feed and water were provided for *ad libitum* consumption. The lighting program provided 23 h of light daily from 1-21 days of age. The room temperature was 35°C at placement until 2 days of age, 32-33°C from 3-7 days of age and 31-32°C from 8-14 days of age.

Birds were observed daily and dead birds were removed and weighed to calculate mortality and adjusted FCR (AdjFCR). Initial pen BW was collected at 1 day of age. Feed consumption and BW by cage were determined at 14 days of age. At 14 days of age, a single bird from each cage was removed and killed, the gizzard was excised and the surrounding fat removed. The gizzard was opened, the contents removed and the gizzard was then rinsed and blotted dry. The gizzard was weighed and expressed as absolute weight and as a percentage of BW. The remaining broiler chicks in each of the cages were transferred to a 96 floor pen house. The birds were then

Table 1: The composition of the broiler starter, grower and finisher diets

Ingredients	Starter (%)	Grower (%)	Finisher (%)
Corn	59.10	67.26	71.55
Soybean meal	36.10	28.18	23.92
Poultry fat	0.50	0.50	0.50
Limestone	0.97	1.02	1.07
Dicalcium phosphate	2.09	1.85	1.57
L-Lysine	0.00	0.06	0.21
DL-Methionine	0.19	0.13	0.10
L-Threonine	0.05	0.00	0.08
Salt	0.50	0.50	0.50
Vitamin premix[1]	0.05	0.05	0.05
Choline chloride (60%)	0.20	0.20	0.20
Trace mineral premix[2]	0.20	0.20	0.20
Coccidiostat[3]	0.05	0.05	0.05
Calculated analysis			
ME (kcal kg^{-1})	2,935.00	3,016.00	3,068.00
Crude protein (%)	23.00	20.00	18.50
Calcium (%)	0.90	0.85	0.80
Total phosphorus (%)	0.75	0.67	0.60
Available phosphorus (%)	0.45	0.40	0.35
Sodium (%)	0.20	0.20	0.20
Lysine (%)	1.26	1.10	1.10
Methionine (%)	0.56	0.47	0.42
TSAA (%)	0.96	0.83	0.75
Threonine (%)	0.89	0.72	0.73
Tryptophan (%)	0.25	0.19	0.17
Leucine (%)	1.96	1.76	1.65

[1]The vitamin premix supplied the following per kilogram of feed: Vitamin A, 6,600 IU; cholecalciferol, 2,000 IU; Vitamin E, 33 IU; Vitamin B12, 19.8 ug; riboflavin, 6.6 mg; niacin, 55 mg; pantothenic acid, 11 mg; Vitamin K, 2 mg; folic acid, 1.1 mg; thiamin, 2 mg; pyridoxine, 4 mg and biotin, 126 mg; [2]The mineral premix supplied the following per kilogram of feed: zinc, 120 mg; manganese, 120 mg; iron, 80 mg; copper, 10 mg; iodine, 2.5 mg; cobalt, 1.0 mg; [3]Monensin was included at 81.65 mg kg^{-1}

grown in the curtain-sided, heated and fan-ventilated broiler house for a subsequent 35 days. Each pen contained one bell-type water and one tube-type feeder with previously used litter that was top-dressed with new pine wood shavings. Birds had *ad libitum* access to feed and water. Each cage was transferred as a group to a floor pen and assigned to one of two feed forms (50 or 100% pellets). The residual starter feed that remained in the battery cages was transferred and placed in the bottom of the floor pen feeder with grower feed placed on top of the starter. This insured that the same total nutrient package was consumed by each bird. Feed consumption and BW by pen were determined at 28, 35, 42 and 49 days of age. At 49 days of age the gizzard of one bird per pen was excised and the surrounding fat removed. The gizzard was opened, the contents removed and the gizzard was rinsed and blotted dry. The gizzard was weighed and expressed on an absolute basis and as a percentage of BW. Feed conversion (AdjFCR) was adjusted for mortality by adding the BW of dead birds to the weight of the live birds in each pen and calculated at 14, 28, 35, 42 and 49 days of age.

The starter phase of the experiment was analyzed as a 2×6 factorial randomized complete block design of sex (male versus female) and feed form (mash, 0, 25, 50, 75 and 100% crumbles). Orthogonal contrast comparisons were conducted to determine linear and quadratic effects of the percentage crumbles in the feed at 14 days of age. In addition, single degree of freedom contrast comparisons were conducted to determine the effect of crumbles in comparison to mash feed for the starter period. The grow-out phase was analyzed as a 2×2 factorial randomized complete block design of sex and feed form (50 versus 100% pellet). Furthermore, the five crumble level treatments fed in the starter phase was used as a factor and analyzed with Proc GLM of SAS to determine if there was a carryover effect of percentage crumbles between the two experimental phases. Data were analyzed with Proc GLM of SAS. Means were partitioned by least square means with statements of statistical significance based on $p<0.05$.

RESULTS AND DISCUSSION

The percentage crumbles in the crumbled starter diets was 8, 38, 52, 75 and 93% for the 0, 25, 50, 75 and 100% treatments, respectively. The percentage pellets was 46 and 97% in the grower and 51 and 83% in the finisher diets for the 50 and 100% pellet treatments, respectively.

The results of the starter phase of this study are shown in Table 2. There was an interaction ($p<0.05$) of sex and feed form on BW at 14 days. The orthogonal contrast indicated that the 14 days BW of the males fed mash was lower as compared to birds fed crumbles which was also observed in the females fed the mash diets. As a group the birds fed the crumbled feed were heavier ($p<0.05$) at 14 days of age as compared to those fed mash feed (488 versus 421 g). The birds fed the crumbled diets also had greater feed intake during the initial 14 days period (Table 2) which resulted in a heavier BW. The BW of the birds fed crumbles increased linearly as the percentage crumbles increased. The 14 days BW of the males and females were similar (478 versus 475) in this study. Neither feed form nor sex had a significant effect on AdjFCR of chicks to 14 days. The birds fed crumbled diets exhibited a lower relative gizzard weight as compared to those fed the mash diet at 14 days (Table 2).

Table 2: Effect of feed form, sex and their interaction on BW, Feed Intake (FI), adjusted Feed Conversion Ratio (AdjFCR) and relative gizzard weight of male and female broilers at 14 days of age

Sex	Feed form	BW (g)	FI (g)	AdjFCR[2] (g:g)	Gizzard (g/100 g BW)
Interaction effects					
Male	Mash	407^{e}	480	1.33	2.60
Male	0% crumbles	472^{d}	551	1.30	2.28
Male	25% crumbles	486^{ad}	572	1.31	2.25
Male	50% crumbles	490^{ad}	599	1.36	2.30
Male	75% crumbles	505^{af}	596	1.30	2.24
Male	100% crumbles	510^{af}	601	1.30	2.13
Female	Mash	435^{c}	488	1.27	2.47
Female	0% crumbles	460^{bd}	528	1.28	2.22
Female	25% crumbles	479^{abd}	569	1.32	2.09
Female	50% crumbles	489^{ad}	580	1.31	2.13
Female	75% crumbles	490^{ad}	577	1.31	2.11
Female	100% crumbles	497^{a}	586	1.30	2.05
SEM	-	8	8	0.02	0.08
Main effects					
	Mash	421^{d}	484^{d}	1.30	2.54^{a}
	0% crumbles	466^{c}	539^{c}	1.29	2.25^{b}
	25% crumbles	482^{b}	570^{b}	1.31	2.17^{bc}
	50% crumbles	490^{ab}	590^{a}	1.34	2.22^{bc}
	75% crumbles	498^{a}	587^{a}	1.31	2.18^{bc}
	100% crumbles	503^{a}	594^{a}	1.30	2.09^{c}
SEM	-	5	5	0.02	0.05
Male	-	478	566^{a}	1.32	2.30^{a}
Female	-	475	555^{b}	1.30	2.18^{b}
SEM	-	3	3	0.01	0.03
Source of variation		p-value			
Form x Sex		0.0499	0.3092	0.3051	0.9769
Feed form		0.0001	0.0001	0.3094	0.0001
Sex		0.4523	0.0092	0.1248	0.0053
Contrast of crumbles		p-value			
Crumbles versus mash		0.0001	0.0001	0.5183	0.0001
Linear		0.0001	0.0001	0.6711	0.0730
Quadratic		0.3084	0.0006	0.0466	0.6094

$^{a-f}$Means within a column with different superscripts differ significantly ($p<0.05$). [1]Treatments consisted of mash diets versus pelleted and crumbled diets with 0, 25, 50, 75 and 100% crumbles fed to male and female broilers. The 0% crumbles diet was pelleted first but only pelleted fines were fed to the broilers as compared to the mash diet that was not subjected to the pelleting process; [2]Values represent the feed conversion ratio after being corrected for mortality

The results of the growing and finishing phase of this experiment are shown in Table 3-7. The BW of the males (1,425, 2,188, 3,027 and 3,897 g) at 28, 35, 42 and

Table 3: Effect of feed form, sex and their interaction on BW of male and female broilers from 15-49 days of age

		Age (days)			
Sex	Pellets[1] (%)	28 g	35 g	42 g	49 g
Interaction effects					
Male	100	1,432[a]	2,243	3,104	3,983
Male	50	1,419[a]	2,134	2,950	3,811
Female	100	1,308[b]	1,921	2,565	3,220
Female	50	1,215[c]	1,777	2,384	3,038
SEM		16	22	26	25
Main effects					
	100	1,370[a]	2,082[a]	2,834[a]	3,602[a]
	50	1,317[b]	1,956[b]	2,667[b]	3,424[b]
SEM	-	11	16	18	18
Male	-	1,425[a]	2,188[a]	3,027[a]	3,897[a]
Female	-	1,262[b]	1,849[b]	2,474[b]	3,128[b]
SEM	-	11	16	18	18
Source of variation		p-value			
Form x Sex		0.0136	0.4377	0.6006	0.8252
Feed form		0.0014	0.0001	0.0001	0.0001
Sex		0.0001	0.0001	0.0001	0.0001

[a,b]Means within a column with different superscripts differ significantly ($p \leq 0.05$); [1]Treatments consisted of 100% pellet diet versus 50% pellet diets fed to male and female broilers from 15-49 days of age

Table 4: Effect of initial percentage crumbles and subsequent percentage of pellets on BW of broilers from 14-35 days of age

	50%			100%		
Pellet[1]	14 g	28 g	35 g	14 g	28 g	35 g
Age (days) crumbles[2] (%)						
0	503[c]	1,280[b]	1,927	525[d]	1,398[ac]	2,082
25	540[b]	1,349[a]	2,005	533[bc]	1,384[ac]	2,093
50	553[ab]	1,308[ab]	1,900	552[ab]	1,389[a]	2,072
75	554[ab]	1,348[a]	1,998	564[a]	1,263[b]	2,068
100	559[a]	1,316[ab]	1,949	566[a]	1,443[a]	2,136
SEM	7.7	17.5	37.7	6.7	30.8	37.3
Source of variation	p-value					
Crumbles	0.0003	0.0461	0.2831	0.0003	0.0124	0.6870

[a-d]Means within a column with different superscripts differ significantly ($p \leq 0.05$); [1]Treatments consisted of 100% pellet diet versus 50% pellet diets fed to male and female broilers from 15 days of age; [2]Treatments consisted of crumbled diets with 0, 25, 50, 75 and 100% crumbles fed to male and female broilers to 14 days of age

49 days, respectively were greater ($p<0.05$) than that of the females (1,262, 1,849, 2,474 and 3,129 g) at the same ages (Table 3). The birds fed 100% pellets were 5% heavier than birds fed 50% pellets (3,602 versus 3,424 g) at 49 days of age (Table 3).

The difference in BW ($p<0.05$) observed at 14 days due to feeding higher quality crumbles in the cages disappeared by 35 days in the floor pen study (Table 4). The males exhibited greater feed intake (Table 5) than females throughout the experiment while broilers fed the 100% pellet diet consumed more feed than birds fed the 50% pellet diet from 15-49 days of age (Table 5). The AdjFCR of the males was improved compared to the females throughout the experiment (Table 6). The improvement in AdjFCR from feeding 100 versus 50% pellets did not become apparent until after 35 days of age.

Table 5: Effect of feed form, sex and their interaction on feed intake of male and female broilers from 15-49 days of age

		Age (days)			
Sex	Pellets[1] (%)	28 g	35 g	42 g	49 g
Interaction effects					
Male	100	1,579	3,014	4,780	6,685
Male	50	1,519	2,829	4,574	6,451
Female	100	1,408	2,596	4,069	5,640
Female	50	1,277	2,331	3,778	5,373
SEM		27	22	52	25
Main effects					
	100	1,493[a]	2,805[a]	4,425[a]	6,163[a]
	50	1,398[b]	2,580[b]	4,176[b]	5,912[b]
SEM	-	19	26	37	44
Male	-	1,549[a]	2,921[a]	4,677[a]	6,568[a]
Female	-	1,342[b]	2,464[b]	3,923[b]	5,507[b]
SEM	-	19	26	37	44
Source of variation		p-value			
Form x Sex		0.1662	0.2602	0.4119	0.7796
Feed form		0.0004	0.0001	0.0001	0.0001
Sex		0.0001	0.0001	0.0001	0.0001

[a,b]Means within a column with different superscripts differ significantly ($p \leq 0.05$). [1]Treatments consisted of 100% pellet diet versus 50% pellet diets fed to male and female broilers from 15-49 days of age

Table 6: Effect of feed form, sex and their interaction on adjusted feed conversion ratio (AdjFCR[2]) of male and female broilers from 15-49 days of age

		Age (days) (g:g)			
Sex	Pellets[1] (%)	28	35	42	49
Interaction effects					
Male	100	1.82[ab]	1.76	1.85	1.95
Male	50	1.71[bc]	1.77	1.91	2.00
Female	100	1.80[b]	1.86	1.99	2.09
Female	50	1.92[a]	1.91	2.06	2.16
SEM	-	0.05	0.02	0.02	0.02
Main effects					
	100	1.81	1.81	1.92[b]	2.02[b]
	50	1.82	1.84	1.98[a]	2.08[a]
SEM	-	0.03	0.02	0.01	0.01
Male	-	1.76[b]	1.77[b]	1.88[b]	1.98[b]
Female	-	1.86[a]	1.88[a]	2.03[a]	2.12[a]
SEM	-	0.03	0.02	0.01	0.01
Source of variation		p-value			
Form x Sex		0.0018	0.3540	0.9555	0.5282
Feed form		0.8352	0.0849	0.0022	0.0096
Sex		0.0106	0.0001	0.0001	0.0001

[a,b]Means within a column with different superscripts differ significantly ($p \leq 0.05$). [1]Treatments consisted of 100% pellet diet versus 50% pellet diets fed to male and female broilers from 15-49 days of age; [2]Values represent the cumulative feed conversion ratio after being corrected for mortality. Starter feed that remained in the cage feeder was transferred to the pen feeder to supply equivalent nutrients to the birds from the starter phase. The starter feed was consumed by approximately 15 days of age

There was a 6 point improvement in AdjFCR (2.02 versus 2.08) at 49 days of age for birds fed 100% pellets as compared to birds fed 50% pellets (Table 6). The relative gizzard weight of birds fed 50% pellets was greater as compared to birds fed 100% pellets (0.43 versus 0.35 g/100 g BW) at 49 days (Table 7).

The results of the starter experiment in cages confirmed that birds fed crumbles in any quantity versus

Table 7: Effect of feed form, sex and their interaction on gizzard weight of male and female broilers at 49 days of age

Sex	Pellets[1] (%)	Gizzard (g)	Relative gizzard (g/100 g BW)
Interaction effects			
Male	100	13.1	0.34
Male	50	15.0	0.40
Female	100	12.2	0.37
Female	50	14.1	0.46
SEM	-	0.7	0.02
Main effects			
	100	12.6[b]	0.35[b]
	50	14.5[a]	0.43[a]
SEM	-	0.5	0.02
Male	-	14.0	0.37[b]
Female	-	13.2	0.42[a]
SEM	-	0.5	0.02
Source of variation		----------p-value----------	
Form x Sex		0.9679	0.5890
Feed form		0.0094	0.0012
Sex		0.2238	0.0404

[a,b]Means within a column with different superscripts differ significantly ($p \leq 0.05$). [1]Treatments consisted of 100% pellet diet versus 50% pellet diets fed to male and female broilers from 15-49 days of age

mash exhibited a higher feed intake which resulted in a greater BW. Although, the addition of fines reduced the growth rate of the birds, the birds fed the highest level of fines (0% crumbles) were heavier than those birds fed the mash diet at 14 days of age. However, most of the positive effect on BW that occurred from feeding high quality crumbles was no longer apparent at 35 days of age after the broilers were moved to the floor pens (Table 4). The data did suggest that birds reared in cages preferred the feed that contained >50% crumbles (Table 2). The results of this study were similar to those of Nir *et al.* (1995) who reported higher BW (2,298 g) with crumbled as compared to mash diets (2,236 g) at 35 days of age in male broilers.

The results of the finishing experiment in floor pens indicated that pelleted feed positively affected BW of both male and female broilers at all ages (Table 3). Broilers fed a diet in 100% pellet form exhibited a consistently higher BW from 14 days of age. The results in the present study were similar to those of other researchers who reported the addition of fines to broiler diets reduced growth in all diet phases (Nir *et al.*, 1995; Engberg *et al.*, 2002; Svihusa *et al.*, 2004; Corzo *et al.*, 2011). These improvements have been variably attributed to increased nutrient density of the pellets, improved starch digestibility due to conditioning and pelleting the mash increased nutrient intake due to the physical form of the feed reduced feed wastage and decreased energy expenditure during feeding (Amerah *et al.*, 2007). However, it appears that within the present study that the improvements were primarily driven by increased feed intake after the birds had finished feathering and nutrients were shifted to other tissue growth. The difference in the BW of the birds fed the 100% pellets was 4.8, 6.4, 6.2 and 5.2% greater than birds fed 50% pellets at 28, 35, 42 and 49 days of age. The corresponding increase in feed intake of the birds fed 100% pellets was 6.8, 8.7, 6.0 and 4.2% greater at the corresponding ages. These data suggest that feeding 50% pellets decreased total feed intake by 4% from 15-49 days of age.

CONCLUSION

The present data demonstrated that the relative gizzard weight was smaller in birds fed crumbled versus mash feed during the 14 days starter phase. Similar findings have been reported by researchers who fed pelleted versus mash diets (Choi *et al.*, 1986) as well as different levels of fines in pelleted diets (Nir *et al.*, 1994). The birds fed the 50% fines (50% pellets) diet from 15 days of age exhibited a larger relative gizzard as compared to birds fed the 100% pellets. These results combined with the lower feed intake suggest that the bird may have a feedback mechanism that increased gizzard activity when feed intake was depressed or that these birds consumed more litter:

- A higher percentage of crumbles and pellets increased feed intake which resulted in a greater BW
- The differences in BW at 14 days of age due to a higher percentage of crumbles in the starter feed did not carry forward to 35 days of age
- The birds fed a higher percentage pellets in the grower and finisher diets were heavier and had improved AdjFCR
- The gizzard was smaller in broilers that had consumed high quality crumbles and pellets

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