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Effect of Feed Form, Corn Particle Size, and Extrusion of Corn on Broiler Performance

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Summary

The pelleting and extrusion processes use both thermal and mechanical energies to alter the crystalline structure of the starch granule, which makes it more digestible than raw starch. The particle size of the ground corn particle in the diet also affects the rate at which gelatinization occurs in the extrusion process. There is limited research on broiler performance when feeding diets that contain different particle sizes of corn prior to extrusion. The objective of this study was to determine the effect of feed form, corn particle size and the extrusion of corn on growth performance of 21-d-old broiler chicks. To determine the effect of corn type on growth performance, treatments were arranged in a 2 × 3 factorial of corn type (raw corn and extruded corn) and corn particle size (400, 800, and 1200 µm). There was no interaction ($P > 0.742$) between corn type and corn particle size on d 21 BW, ADFI, or feed conversion ratio (FCR). Broilers fed the raw corn diet had greater ($P < 0.001$) d 21 BW and ADFI compared to those fed the extruded corn diets. There was no evidence of difference ($P > 0.081$) in d 21 BW and ADFI in broilers fed the three different corn particle sizes. Broilers fed diets with increasing corn particle size had increased (linear, $P = 0.015$) FCR. There was an interaction ($P < 0.039$) between corn type and corn particle size on both the relative gizzard and pancreas weights of broilers. To determine the effects of feed form on growth performance and relative gizzard and pancreas weight, treatments were arranged in a 2 × 2 factorial of feed form (mash and crumble feed) and corn particle size (400 and 800 µm). There was no evidence of interaction ($P > 0.180$) between feed form and corn particle size on growth performance or relative gizzard and pancreas weight. Broilers fed the crumble extruded corn diet had increased ($P = 0.001$) d 21 BW and ADFI compared to those fed the mash extruded corn diets. There was no evidence of difference ($P > 0.189$) in d 21 BW, ADFI, and FCR between broilers fed extruded diets containing 400 µm corn and 800 µm corn regardless of feed form. Broilers fed the mash extruded corn diet had greater ($P < 0.001$) relative gizzard and pancreas weights as compared to those fed the crumbled extruded corn diets. In addition, broiler relative gizzard weight was greater ($P = 0.002$) for those fed the extruded corn diet containing 800 µm versus 400 µm corn, while there was no evidence of difference in relative pancreas weight. Therefore, increasing the amount of gelatinized starch in the feed by replacing ground corn with extruded corn in a broiler starter diet did not improve growth performance. Increasing corn particle size led to improved gizzard development.

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Introduction

A greater percentage of the starch is gelatinized in the extrusion process due to the higher mechanical shear, as well as a higher temperature and moisture content as compared to the pelleting process. Starch gelatinization is a process of breaking down the crystal structure of starch granules. The first step in the gelatinization process is to loosen the hydrogen bonds. The starch granule swells as water is absorbed and then thermal energy is added, which causes a loss of birefringence.[2] Previous research has demonstrated that increasing starch gelatinization through thermal processing increases the apparent metabolizable energy (AME) as compared to feeding the mash diet containing ground corn.[3] There is limited research on broiler performance when birds are fed diets that contain different original particle sizes of corn prior to extrusion. The objective of this study was to determine the effect of feed form, corn particle size, and extrusion of corn on growth performance of 21-d-old broiler chicks.

Procedures

Ingredients and extrusion conditions

Corn was ground with a 3-high roller mill (RMS Roller-Grinder Model 924, Harrisburg, SD) to three target particle sizes: 400, 800, and 1,200 µm. The three ground corn particle sizes were then extruded at 266–284°F using a single screw extruder (Wenger Manufacturing model X20, Sabetha, KS) equipped with a ¼ in. die. The length-diameter ratio of the screw was 10:1. The extruded corn was dried at 219°F for 18 min and then cooled for 7 min using a belt dryer (Wenger Manufacturing model 4800, Sabetha, KS).

Diet

A corn-soy broiler starter diet was formulated to meet or exceed the requirements of Cobb 500 nutrient recommendation (Cobb-Vantress, 2015; Table 1). Formulation was the same across treatments. Three corn particle sizes (400, 800, and 1,200 µm) were fed as unprocessed or extruded. Prior to mixing, the three extruded corn particles size treatments were reground using a single pair crumble roll (Colorado Mill Equipment model EcoRoll 7, Canon City, CO). Diets were mixed for 5 minutes in a 200-lb paddle mixer (Davis Model 2014197-SS-S1, Bonner Spring, KS). Diets containing the raw corn were steam conditioned at approximately 174°F for 18 s and pelleted using a pellet mill (California Pellet Mill model CL-5, Crawfordsville, IN) equipped with a 5⁄32 in. × ⅞ in. die. Diets containing the extruded corn were steam conditioned at 156°F for approximately 18 s and pelleted using the same pellet mill equipped with a 5⁄32 in. × ½ in. die. The feeder setting was held constant at approximately 2.2 lb per min. Die thickness and conditioning temperature were chosen to achieve good pellet quality, while facilitating smooth operation. All pelleted diets were crumbled using the single pair crumble roll. There were a total of 8 treatments that consisted of six crumble diets with 400, 800, or 1200 µm either raw corn (CRC) or extruded corn (CEC) and two mash diets with 400 or 800 µm extruded corn (MEC) to provide a total of eight dietary treatments.

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[2] Buleon, A., Colonna, P. "Thermal Transitions of Starches." Starches; characterization, properties, and applications. Ed. by Andrea C. Bertolini. Scitech Book News 34, no. 2 (2010), pp. 72-94.

[3] Moritz, J., A. Parsons, N. Buchanan, and W. Calvalcanti. "Effect of Gelatinizing Dietary Starch Through Feed Processing on Zero- to Three-Week Broiler Performance and Metabolism." Journal of Applied Poultry Research 14, no. 1 (2005): 47-54.

The pelleted complete diets were analyzed for total, gelatinized, and cooked starch and described as follows.

Broiler feeding experiment

All handling procedures and euthanasia protocols were carried out in accordance with the guidelines approved by the Institutional Animal Care and Use Committee of Kansas State University. A 21-d battery trial was conducted utilizing 320 male Cobb 500 broiler chicks. Birds were randomly allotted to one of eight dietary treatments and placed with 5 birds per cage, totaling 8 replicate cages per treatment. As described previously, treatments were formulated with 400, 800, or 1,200 μm ground corn and 400, 800, or 1,200 μm extruded corn. There were eight dietary treatments: three CRC diets, three CEC diets and two MEC diets. The BW and feed disappearance were collected at 7, 14, and 21 d. Average daily gain and FCR were calculated and adjusted for mortality. At d 21, two birds of the approximated average weight of the birds in the cage were euthanized via cervical dislocation to collect gizzard and pancreas weights.

Data collection

The pellet durability index (PDI) was analyzed according to ASAE 269.5.[4] The sample was sifted with a U.S. No. 6 (5/32 in.) sieve. A 500-g sample of sifted pellets was placed in the tumble box for 10 min. The sample was sifted again with the same sieve. The PDI was calculated by dividing the whole pellets after tumbling by the initial sample weight and then multiplying by 100. The PDI procedure was modified by adding three ¾ in. hex nuts to the tumble box and tumbling for 10 min.

Composite pellet samples were analyzed for total starch, gelatinized starch, and cooked starch. Samples for starch analysis were sent to the Wenger Technical Center Laboratory (Sabetha, KS) and were analyzed by methods outlined by Mason et al.[5] Briefly, one 0.5-g subsample was hydrolyzed in distilled water at room temperature while a second 0.5-g subsample was boiled with distilled water. Samples were incubated with glucoamylase, and free D-glucose was measured. The quantity of free glucose analyzed in the room temperature sample represented the percentage of starch that was gelatinized during processing, and the quantity of free glucose in the boiled sample represented the percentage of total starch in the sample. Cooked starch was then calculated as the percentage of gelatinized starch divided by the percentage of total starch multiplied by 100.

Particle size was determined with a Ro-Tap sieve shaker (model RX-29; W.S. Tyler Industrial Group, Mentor, Ohio) using the method of determining and expressing fineness of feed materials by sieving (ANSI/ASABE S319.2)[4] with 0.5 g of flow agent for 10 min.

Statistical analysis

Data were analyzed as a completely randomized design. For the corn type effect, treatments were analyzed as a 2 × 3 factorial of corn type (raw corn and extruded corn)

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[4] ASAE. 2012. Densified Products for Bulk Handling-Definitions and Method. ASAE Standard S269.5. American Society of Agricultural and Biological Engineers, St. Joseph, MI.

[5] Mason, M., B. Gleason, and G. Rokey. 1982. A new method for determining degree of cook. Proceedings of the American Association of Cereal Chemists 67th Annual Meeting. P. 123-124. San Antonio, TX, USA.

and corn particle size (400, 800, and 1200 μm) to determine the effect on growth performance and relative gizzard and pancreas weight. For feed form effect, treatments were analyzed as a 2 × 2 factorial of feed form (mash feed and crumble feed) and corn particle size (400 and 800 μm) to determine the effect of growth performance and relative gizzard and pancreas weight. There were 8 replicates per treatment for both corn type and feed form effects. Data were analyzed using the GLIMMIX procedure of SAS. Means were separated by least squares means. Results were considered significant at $P \leq 0.05$.

Results and Discussion

The raw ground corn particle sizes were 396, 795, and 1,204 μm for 400, 800, and 1200 μm treatments, respectively. The reground extruded corn particle sizes were 1,343, 1,668, and 1,732 μm for 400, 800, and 1200 μm treatments, respectively. The gap of the crumble roll was the same across all extruded treatments. However, the difference in the reground extruded corn particle sizes may be due to the difference in the amount of gelatinized starch in the extruded corn. The amount of gelatinized starch was greater in the extruded corn compared to the raw corn by 46 to 58% (Table 2). Decreasing the initial corn particle size increased the percent gelatinized starch. This was to be expected since steam and heat penetrations were better with smaller corn particles than larger corn particles.

The particle size of the mash feed was 497, 722, and 943 for crumble with 400, 800, and 1200 μm raw corn, respectively. The particle size of the mash feed was 1,157, 1,195, and 1,363 μm for crumble with 400, 800, and 1200 μm extruded corn, respectively. Both the PDI and modified PDI of the pelleted feed before crumbling was above 91% for all crumble feed. The crumble feed with raw corn had greater gelatinized starch than the actual raw corn regardless of particle size. The % cooked starch between the extruded corn and diets containing extruded corn were similar. The pelleting process increased the percentage of cooked starch by 14% as compared to mash diets with raw corn while the pelleted diets with extruded corn had similar % cooked starch to their mash diets.

There was no evidence of interaction ($P > 0.371$) between corn type and corn particle size for d 21 BW, ADFI, and FCR (Table 3). Broilers fed the raw corn diet had increased ($P < 0.001$) d 21 BW and ADFI and tendency for improved ($P = 0.075$) FCR compared to those fed the extruded corn diets. Broilers fed diets with increasing corn particle size tended to have poorer (linear, $P = 0.081$) d 21 BW and had poorer (linear, $P = 0.015$) FCR. There was no evidence of difference in broiler ADFI when fed different corn particle sizes. There was an interaction ($P = 0.006$) between corn type and corn particle size on relative gizzard weight. Broilers fed the raw corn diet had increased gizzard weight as compared to broilers fed the extruded corn diet when the corn particle sizes were 400 and 800 μm. However, there was no difference in relative gizzard weight for broilers between the raw corn diet and extruded corn diet when the corn particle size was 1200 μm. There was an interaction ($P = 0.039$) between corn type and corn particle size on relative pancreas weight. The birds fed the extruded corn diet with 1200 μm corn had larger relative pancreas weight as compared to the extruded corn diets with 400 and 800 μm corn. However, there was no difference in relative pancreas weight among the raw corn diets with the three different corn particle sizes.

For feed form effect, treatments were analyzed in a 2 × 2 factorial of feed form (mash and crumble feed) and corn particle size (400 and 800 μm) to determine the effects on growth performance and relative gizzard and pancreas weight. There was no evidence of interaction ($P > 0.180$) between feed form and corn particle size on growth performance or relative gizzard and pancreas weight. Broilers fed the crumble extruded corn diet had increased ($P = 0.001$) d 21 BW and ADFI compared to those fed the mash extruded corn diets. There was no evidence of difference ($P > 0.189$) in d 21 BW, ADFI, and FCR between broilers fed extruded diets containing 400 μm corn versus 800 μm corn regardless of feed form. Broilers fed the mash raw corn diet had greater ($P < 0.001$) relative gizzard and pancreas weights as compared to those fed the mash extruded corn diets. In addition, broiler relative gizzard weight was greater ($P = 0.002$) for those fed the extruded corn diet containing 800 μm versus 400 μm corn, while there was no evidence of difference in relative pancreas weight.

The results of this study indicated that increasing the amount of gelatinized starch in the feed by replacing ground corn with extruded corn in a broiler starter diet did not improve growth performance. Increasing corn particle size led to improved gizzard development. However, increasing the corn particle size from 400 to 1200 μm resulted in poorer FCR.

Table 1. Compositions of broiler starter diets

	Raw ground corn			Extruded corn[1]		
Ingredients	**400 µm**	**800 µm**	**1200 µm**	**400 µm**	**800 µm**	**1200 µm**
Corn	59.71	59.71	59.71	59.71	59.71	59.71
Soybean meal	34.60	34.60	34.60	34.60	34.60	34.60
Soy oil	1.00	1.00	1.00	1.00	1.00	1.00
Mono-calcium phosphate, 21% P	2.10	2.10	2.10	2.10	2.10	2.10
Limestone	1.40	1.40	1.40	1.40	1.40	1.40
Poultry vitamin and mineral premix[2]	0.25	0.25	0.25	0.25	0.25	0.25
L-Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.28	0.28	0.28	0.28	0.28	0.28
L-Threonine	0.08	0.08	0.08	0.08	0.08	0.08
Sodium bicarbonate	0.20	0.20	0.20	0.20	0.20	0.20
Salt	0.23	0.23	0.23	0.23	0.23	0.23
Calculated analysis						
Crude protein, %	22.10	22.10	22.10	22.10	22.10	22.10
Crude fat, %	3.37	3.37	3.37	3.37	3.37	3.37
ME, kcal/kg	1382	1382	1382	1382	1382	1382

[1]Three ground corn particle sizes were extruded at 266–284°F using a single screw extruder equipped with ¼ in. die then reground using a single pair crumble roll.

[2]Composition per kilogram: 20 g iron, 40 g zinc, 40 g manganese, 4.5 g copper, 0.6 g iodine, and 0.06 g selenium. 3,080,000 IU vitamin A, 1,100,000 IU vitamin D_3, 6,600 IU vitamin E, 4.4 mg vitamin B_{12}, 330 mg menadione, 2,640 mg riboflavin, 2,640 mg d-pantothenic acid, and 11,000 mg niacin.

Table 2. Starch analysis of raw corn, extruded corn, and diets and pellet quality of pellets before crumbling

	Particle size[1], µm						
Item	d_{gw}	S_{gw}	Total starch, %	Gelatinized starch, %	Cooked starch, %	PDI,[2] %	Modified PDI,[3] %
400 µm ground raw corn	396	2.22	77.17	8.76	11.4	-	-
800 µm ground raw corn	795	2.08	71.91	6.95	9.70	-	-
1200 µm ground raw corn	1,204	2.18	70.46	8.12	11.5	-	-
Mash feed, 400 µm raw corn	497	2.63	44.70	7.50	16.8	-	-
Mash feed, 800 µm raw corn	722	2.57	46.23	7.15	15.5	-	-
Mash feed, 1200 µm raw corn	943	2.48	43.45	6.97	16.0	-	-
Crumble feed, 400 µm raw corn			48.62	15.27	31.4	97.5	93.5
Crumble feed, 800 µm raw corn			49.78	14.51	29.1	97.5	93.0
Crumble feed, 1200 µm raw corn			46.24	14.42	31.2	97.4	93.0
400 µm extruded corn[4]	1,343	2.24	76.71	66.56	86.8	-	-
800 µm extruded corn[4]	1,668	2.06	75.72	60.13	79.4	-	-
1200 µm extruded corn[4]	1,732	2.25	73.68	54.59	74.1	-	-
Mash feed, 400 µm extruded corn	1,157	2.22	45.90	39.23	85.5	-	-
Mash feed, 800 µm extruded corn	1,195	2.26	44.29	37.47	84.6	-	-
Mash feed, 1200 µm extruded corn	1,363	2.18	44.96	32.25	71.7	-	-
Crumble feed, 400 µm extruded corn			49.22	42.94	87.3	97.2	94.7
Crumble feed, 800 µm extruded corn			48.84	40.63	83.2	95.1	91.3
Crumble feed, 1200 µm extruded corn			47.35	33.30	70.4	95.8	92.8

[1]Particle size was determined by ASAE S319.2 with a 0.5 g flow agent for 10 min running time and reported in geometric mean diameter (d_{gw}) and geometric standard deviation (S_{gw}).
[2]Pellet durability index (PDI) was determined by ASAE S269.5.
[3]The PDI procedure was modified by adding three ¾ in. hex nuts to the tumble box and tumbling for 10 minutes.
[4]The particle sizes were analyzed after extruded corn products were reground using a single pair crumble roll.

Table 3. Effect of corn type and corn particle size on growth performance and relative gizzard and pancreas weight of male broilers at 21 d[1]

Corn type:	Raw corn			Extruded corn				Probability, *P* <			
										Corn particle size	
Corn particle size[2]:	400 µm	800 µm	1200 µm	400 µm	800 µm	1200 µm	SEM	Interaction	Corn type	Linear	Quadratic
BW, lb	1.92	1.90	1.85	1.76	1.72	1.72	0.059	0.742	0.001	0.081	0.976
ADFI, lb	0.109	0.114	0.111	0.100	0.103	0.101	0.0022	0.858	0.001	0.478	0.135
FCR	1.28	1.31	1.33	1.31	1.34	1.32	0.018	0.371	0.075	0.015	0.210
Gizzard, % of BW	1.54[bc]	1.69[ab]	1.71[a]	1.33[d]	1.50[c]	1.82[a]	0.082	0.006	0.035	0.001	0.917
Pancreas, % of BW	0.28[a]	0.29[a]	0.28[a]	0.24[b]	0.24[b]	0.29[a]	0.016	0.039	0.001	0.008	0.366

[1]At hatch, 320 male broilers (Cobb 500, Cobb-Vantress, Siloam Springs, AR) were placed in battery cages with 5 broilers per cage and 8 replicates per treatment.
[2]The particle size of initial ground corn samples.
[a-b]Means in a column within a main effect of corn type followed by different letter are significantly different ($P \leq 0.05$).
FCR = feed conversion ratio.

Table 4. Effect of feed form and extruded corn on growth performance and relative gizzard and pancreas weight of male broilers at 21d[1]

Diet type:	Crumble		Mash			Probability, *P* <		
Corn particle size[2]:	400 µm	800 µm	400 µm	800 µm	SEM	Interaction	Feed form	Particle size
BW, lb	1.76	1.72	1.54	1.57	0.056	0.253	0.001	0.996
ADFI, lb	0.100	0.103	0.090	0.093	0.0020	0.891	0.001	0.189
FCR	1.31	1.34	1.34	1.34	0.017	0.180	0.179	0.371
Gizzard, % of BW	1.33	1.50	1.67	1.86	0.075	0.842	0.001	0.002
Pancreas, % of BW	0.24	0.24	0.27	0.29	0.015	0.528	0.001	0.263

[1]At hatch, 320 male broilers (Cobb 500, Cobb-Vantress, Siloam Springs, AR) were placed in battery cages with 5 broilers per cage and 8 replicates per treatment.
[2]The particle size of initial ground corn samples.
FCR = feed conversion ratio.