Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X Oct - Dec 2011 / v.13 / n.4 / 227-234

Corn Texture and Particle Size in Broiler Diets

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■Keywords

Carcass traits, digestibility, GMD, particle size, performance.

Submitted: August/2010
Approved: July/2011

ABSTRACT

The objective of this study was to evaluate the effect of corn texture and the particle size on broiler performance, carcass yield, nutrient digestibility, and digestive organ morphometrics. In Experiment I, 720 male Cobb chicks were distributed in a completely randomized experimental design with a 2 x 3 factorial arrangement, consisting two corn textures (dented and hard) and three corn particle sizes, was applied, with four replicates of 30 birds each. Corn particle size was classified according to geometric mean diameter (GMD) as fine – 0.46 mm; medium – 0.73 mm, and coarse – 0.87 mm. In Experiment II, 120 broiler chicks were used to evaluate corn digestibility during the periods of 16 to 22 days and 35 to 41 days of age, using the method of total excreta collection. In Experiment I, corn particle size influenced body weight, average weight gain, feed intake and feed conversion ratio of 21-day-old birds. Corn texture and particle size did not affect the performance of 42-day-old broilers or carcass traits. In Experiment II, there was no influence of corn texture and particle size on digestive organ weights. Dented corn increased nitrogen excretion in the first trial, and hard corn improved dry matter digestibility in the second metabolic trial. Corn with fine particle size promotes better performance of broilers at 21 days of age. Hard corn results in higher dry matter digestibility and lower nitrogen excretion, and consequently higher production factor in 42-day-old broilers.

INTRODUCTION

Corn is the third most cultivated cereal in the world, following wheat and rice. Brazilian poultry and swine industries use approximately 70 to 80% of locally produced corn. Broiler feeds represent more than two thirds of total broiler production cost, and because corn is used as the main energy feedstuff of broiler feeds, its production and processing strongly influence the profitability of the poultry industry (Lott *et al.*, 1992).

The grain texture is mainly defined by the ratio between vitreous and starchy endosperm (Shull *et al.*, 1990). According to grain characteristics, corn is classified in six classes: dent, flint, flour, popcorn, sweet, and waxy. Most of the corn produced in Brazil is flint corn, whereas in temperate climate, dent corn is predominant. In dent corn, the floury endosperm is concentrated in the central area of the grain, between the tip and the top, with the vitreous endosperm located on the sides and back of the grain. Hard corn has a continuous volume on vitreous endosperm, resulting on smoother and rounder grains, with a hard and vitreous appearance (Paes, 2006).

Corn quality losses caused by the action of insects and fungi have driven researchers to seek varieties with better health characteristics, such as thicker husks and hard and semi-hard grains instead of soft grains (Lima, 2001). However, in feed milling, hard corn requires more energy for grinding and impairs particle-size uniformity. Moreover, higher concentrations of digestive enzymes are required to allow animals to properly digest these grains due to their vitreous characteristics (Silva *et al*., 2006).

Particle size has a strong influence on feed intake regulation. Poultry, for instance, prefer diets with larger particle sizes as compared to finely-ground feeds (Jensen *et al*., 1962; Nir *et al*., 1990; Yo *et al*., 1997), and the consumption of diets with different particle sized may directly affect their performance and digestive tract morphology (Nir, 1998).

Grinding determines feed particle size, which can range from very fine to very coarse, according to the diameter of the sieve used in the grinder. Therefore, it may be possible to reduce costs by generating more accurate information on corn grinding in order to determine the particle size that allows the best utilization of nutrients by the birds. Coarse corn grinding increase grinder yield in up to 143%, and reduce electric energy consumption in 61%, with no effect on nutrient digestibility and broiler performance (Zanotto *et al*., 1994).

Nir *et al*. (1994) observed that young broilers presented better performance when fed grain particles sizes with 0.769 mm geometric mean diameter (GMD). The authors detected that the gizzard of broilers fed finely-ground grains was lighter and gastric pH was higher than in broilers fed larger particles, and argued that broiler performance was influenced by these physiological changes.

Zanotto & Bellaver (1996) suggested that the passage rate of larger particles through the gizzard is slower than that of small particles, and observed that 21-d-old broilers fed diets with GMD of 0.716 and 1.196 mm, presented better performance when fed diets with larger particle size.

The nutritional value of corn ground in hammer mills is usually not affected when its GMD is between 0.500 and 1.000 mm, as shown by some authors (Nir *et al*., 1994, Magro *et al*., 2002). However, if corn is too coarse or too fine, birds may not properly utilize corn nutrients. Very fine corn (GMD < 0.400 mm) is mash and/or crumbled feeds may impair feed intake due to the presence of dust, which may cause respiratory disorders, increase water intake, feed presence in the drinkers, and increase litter moisture (Brum *et al*., 1998).

When evaluating different corn particle sizes (781 950, 1042, 1109, 2242μm) in broiler diets, Parsons *et al*. (2006) found better feed efficiency and higher feed intake with increasing particle size, whereas weight gain was not affected.

In order to reduce production costs and increase profitability of broiler production, corn particle sizes that allow proper acceptance by the birds, promote the best nutrient digestibility and performance, maintain bird health, and are economically viable should be identified. Particle size has an important influence on broiler performance and production costs, as it directly affects feed intake.

The present study aimed at evaluating the effect of corn texture and particle size on the broiler performance, carcass yield, nutrient digestibility, and intestinal morphometrics.

MATERIAL AND METHODS

Two experiments were carried out in the Faculdade de Medicina Veterinária e Zootecnia, Univ. Estadual Paulista (UNESP), campus de Botucatu, DMNA, Laboratório de Nutrição de Aves, São Paulo, Brazil.

In Experiment I, 720 one-day-old male Cobb broilers were housed in 24 pens measuring 2.5 m^2 each. Water and feed were supplied *ad libitum* in bell drinkers, and trough feeders, respectively. A completely randomized experimental design, with a 2 x 3 factorial arrangement, consisting two corn textures (dented and hard) and three corn particle sizes, was applied, with four replicates of 30 birds each. Corn particle size was classified according to geometric mean diameter (GMD) as fine – 0.46 mm; medium – 0.73 mm, and coarse – 0.87 mm. The following corn hybrid varieties were used: AG 4051 for dented texture and DAW 2B 710 for hard texture.

Five sieve sizes were used during milling (4, 6, 8, 10 and 12 mm) to obtain fine, medium and coarse particle sizes of the dented and hard corn, which were determined according to the feedstuff particle size determination method proposed by Zanotto & Bellaver (1996). The 4mm sieve was used to obtain fine GMD hard corn; the 6 mm sieve to obtain fine GMD dented corn; the 8 mm sieve to obtain medium GMD dented and hard corn; the 10 mm sieve to obtain coarse GMD hard corn; and the 10 mm sieve to obtain coarse GMD dented corn. A mil with nine knives measuring eight centimeters each, with a total helix diameter of 26 cm and a 25-cv, 3510-rpm electrical engine, was used.

The experimental feeds were iso-nutritious, and formulated on corn and soybean meal basis. Feedstuff composition and nutritional requirements were obtained from the recommendations of Rostagno *et al*. (2005) for intermediate-performance male broilers. The feeding schedule was divided in four phases: pre-starter (1-7 days), starter (8-21 days), grower (22-35 days) and finisher (36-42 days) (Table 1).

Table 1 – Ingredient composition and calculated nutritional values of the experimental diets fed during pre-starter (1-7 days of age), starter (8-21 days), grower (22-35 days) and finisher (36-42 days).

Ingredients (%)	**PHASES**			
	Pre-starter	**Starter**	**Grower**	**Finisher**
Corn	55.730	59.050	61.865	66.300
Soybean meal	37.440	34.480	30.890	26.970
Soybean oil	2.220	2.380	3.350	3.210
Salt	0.260	0.240	0.230	0.210
Calcitic limestone	0.920	0.880	0.830	0.800
Dicalcium phosphate	1.950	1.800	1.670	1.520
DL-methionine	0.245	0.175	0.175	0.165
L-lysine	0.375	0.215	0.230	0.275
Vit. and Min Supp.[1]	0.500	0.400	0.400	0.200
Sodium bicarbonate	0.360	0.380	0.360	0.350
Total	100	100	100	100
Calculated values				
Metabolizable energy (kcal/kg)	2950	3000	3100	3150
Crude protein (%)	22.04	20.79	19.41	18.03
Calcium (%)	0.94	0.88	0.82	0.76
Available phosphorus (%)	0.47	0.44	0.41	0.38
Methionine (%)	0.58	0.49	0.48	0.45
Sulfur amino acids (%)	0.92	0.82	0.79	0.74
Lysine (%)	1.47	1.27	1.19	1.12
Potassium (%)	0.84	0.80	0.74	0.68
Sodium (%)	0.22	0.22	0.21	0.20
Chlorine (%)	0.20	0.19	0.18	0.17
Linoleic acid (%)	2.47	2.60	3.15	3.13

1 - Vitamin and mineral supplement Vaccinar Nutrição e Saúde Animal (per kg feed): folic acid 1.25 mg, pantothenic acid 12.5 mg, B.H.T. 2.5 mg, biotin 0.125 mg, copper 12.5 mg, choline 750.0 mg, iron 62.62 mg, iodine 0.025 mg, manganese 67.5 mg, niacin 37.5 mg, selenium 0.225 mg, vitamin A 12,500 IU, vitamin B1 2.5 mg, vitamin B12 25 mg, vitamin B2 5.0 mg, vitamin B6 5.0 mg, vitamin D3 2,500 IU, vitamin E 25.0 mg, vitamin K3 2.5 mg, zinc 68.75 mg, avilamycin 7.5 mg, monensin 125.0 mg.

Performance data were obtained for the cumulative periods of 1 to 7; 1 to 21 and 1 to 42 days of age. When birds were 42 days of age, five birds per experimental unit were randomly selected, identified, fasted for eight hours, and weighed before slaughter. These birds were submitted to electrical stunning, bled, defeathered, and eviscerated. The fat in the abdominal cavity and adhered to the gizzard was removed. The carcass with no feet, head, or neck was weighed, and carcass yield was calculated relative to live weight immediately before slaughter. Carcasses were then cut up to determine parts yield (breast, thigh and drumstick, back, and wings) relative to carcass weight. Feet, head+neck, abdominal fat yields were calculated relative to live weight before slaughter. Gizzard relative weight was determined after the removal of the proventriculus.

In Experiment II, 120 male broiler chicks were distributed in a completely randomized experimental design, with a 2 x 3 factorial arrangement, consisting two corn textures (dented and hard) and three corn particle sizes, with four replicates of five and two birds in the first and second metabolism trial, respectively. Birds were housed in metabolic cages and the experimental feeds, which were the same as those supplied in Experiment I, were offered from the first day of age.

The metabolism trials were carried out during the periods of 16 to 22 days of age (starter phase) and 35 to 41 days of age (finisher phase). At the end of each experimental period, one bird per experimental unit was removed to determine organ morphometrics. In the first metabolic trial, birds were housed in galvanized steel battery cages, and in the second trial, they were housed in galvanized steel metabolic cages. Cages were equipped with nipple drinkers and trough feeders in both assays.

The metabolic trials were carried out for seven days, divided in three days for bird adaptation to the cages and to the experimental diets and four days for collection. Excreta were collected twice daily (in the morning and in the evening) using the method of total excreta collection. Excreta collected from the tray placed under each cage were identified and stored in a freezer (-10 °C) and subsequently homogenized for analyses. Feeds were weighed before supply, and after the four collection days to determine feed intake.

At the end of the collection period, excreta were thawed, homogenized, pre-dried at 65 °C in a forced-ventilation oven for 48 hours, after which they were ground for subsequent laboratory analysis. The coefficient of dry matter digestibility (CDMD) and nitrogen value were determined according to the method proposed by Silva & Queiroz (2002). Total nitrogen contente was determined using the micro-Kjeldahl method. The following equations used to calculate CDMD and nitrogen balance (NB):

NB (g) = N intake – N excretion;

CDMD (%) or NB (%) = [(Nutrient intake – Nutrient excretion) / Nutrient intake] x 100.

At the end of each metabolism trial, one bird per experimental unit was removed, fasted for six hours, weighed, and sacrificed by neck dislocation. The relative weights of proventriculus+gizzard, small intestine, large intestine, pancreas, liver with gall bladder, and small + large intestine length were determined.

Data were submitted to analysis of variance (ANOVA), using the GLM procedure of SAS (1996) statistical package. When necessary, treatment means were compared by the test of Tukey at 5% probability level.

RESULTS AND DISCUSSION

Corn texture influenced ($p<0.05$) body weight and weight gain of seven-day-old broilers. Those fed dented corn presented higher body weight and weight gain than those fed hard corn (Table 2).

There was an interaction ($p<0.05$) between particle size and texture for feed intake and feed conversion ratio at seven days of age (Table 3). When dented corn was used, there was effect of particle sizes on feed intake, whereas when hard corn was fed, the broilers fed fine particle size presented lower feed intake ($p<0.05$). Also, when fine particle size was used, dented corn promoted higher feed intake than hard corn ($p<0.05$).

Out of the broilers fed dented corn, those fed coarse particle size presented worse feed conversion ratio ($p<0.05$) (Table 3), and when hard corn was fed, the best feed conversion ratio was obtained with fine particle size ($p<0.05$). As to medium particle size, birds fed hard corn presented the worse feed conversion ratio relative to those receiving dented corn ($p<0.05$). Corn texture did not influence feed conversion ratio at seven days of age when fine or coarse particle size were fed. Although dented corn promoted higher body weight and weight gain at seven days of age (Table 2), hard corn with fine particle size fine resulted in the lowest feed intake and best feed conversion ratio (Table 3).

Table 3 – Details of the interactions between corn particle size and texture for feed intake and feed conversion ratio at seven days of age.

Texture	Particle size			Medium
	Fine (0.46mm)	Medium (0.73mm)	Coarse (0.87mm)	
Feed intake, g				
Dented	140 A	139	142	141
Hard	133 Bb	141 a	139 a	138
Medium	137	140	141	
Feed conversion ratio				
Dented	1.148 a	1.144 Aa	1.184 b	1.159
Hard	1.135 a	1.194 Bb	1.168 b	1.166
Medium	1.142	1.169	1.176	

Means followed by different capital letters in the same column and small letters in the same row are different ($p<0.05$) by the test of Tukey.

Particle size influenced ($p<0.05$) body weight,

Table 2 – Initial weight (IW), body weight (BW), weight gain (WG), feed intake (FI), feed conversion ratio (FCR), livability (L) and production factor (PF) in the cumulative periods of 1-7, 1-21 and 1-42 days of age of broiler fed diets with three different particle sizes and two different corn textures.

Variáveis (%)	Particle size (PS)			Texture (T)		P value			CV
	Fine (0.46mm)	Medium (0.73mm)	Coarse (0.87mm)	Dented	Hard	PS	T	PSxT	
7 days of age									
IW, g	46	46	46	46	46	ns	ns	ns	0.66
BW, g	166	166	165	168a	164b	ns	0.001	ns	1.25
WG, g	120	120	120	122a	118b	ns	0.001	ns	1.72
FI, g	137	140	141	141	138	0.03	0.02	0.02	1.94
FCR	1.14	1.17	1.18	1.16	1.17	0.004	ns	0.004	1.55
L, %	99.58	100.00	99.58	99.44	100.00	ns	ns	ns	0.96
21 days of age									
BW, g	929 a	914 ab	913 b	924	914	0.02	ns	ns	1.32
WG, g	884 a	868 ab	867 b	878	868	0.03	ns	ns	1.40
FI, g	1230 b	1279 a	1275 ab	1276	1247	0.03	ns	ns	2.85
FCR	1.39 b	1.48 a	1.47 a	1.46	1.44	0.001	ns	ns	2.04
L, %	99.16	99.16	98.75	99.16	98.88	ns	ns	ns	2.06
42 days of age									
BW, g	2799	2771	2750	2754	2793	ns	ns	ns	3.67
WG, g	2753	2725	2704	2708	2747	ns	ns	ns	3.72
FI, g	5030	5059	5045	5048	5041	ns	ns	ns	1.50
FCR	1.84	1.87	1.88	1.88	1.84	ns	ns	ns	2.77
L, %	97.08	95.42	95.83	95.00	97.22	ns	ns	ns	4.28
PF[1]	346	331	328	326b	344a	ns	0.02	ns	5.31

1 - Production Factor = ((DWG x Livability)/FCR) x 100. Means followed by different small letters in the same row are different ($p<0.05$) by the test of Tukey.

weight gain, feed intake and feed conversion ratio (Table 2). Body weight and weight gain of the broilers fed fine particle size were higher than those fed coarse particle size, differently from the findings of Nir *et al*. (1994), who obtained the best performance in young broilers fed particles with a GMD of 0.769 mm. Feed intake was lower when broilers were fed corn with fine particle size compared with those fed particle medium size. However, birds receiving corn with fine particle size presented better feed conversion ratio than those fed medium or coarse particle size. These results are also opposed to those reported by Deaton *et al*. (1995), who did not observe any differences in the performance parameters of broiler fed diets with particles sizes of 0.679, 0.987 or 1.289 mm GMD.

The results obtained in the present study when broilers were 21 days of age are consistent with the findings of Zanotto & Bellaver (1996), who observed that 1- to 21-day-old broilers fed diets with corn particles sizes of 0.716 and 1.196 mm GMD presented worse performance than those fed a diet with coarse particle size. Those authors mentioned that large particles promote very slow feed passage in the gizzard, consequently compromising broiler performance.

Factori *et al*. (2008) concluded that dented corn with a small particle size GMD (0.570 mm) reduced energy use for grinding compared to hard corn, but there was no influence on broiler performance, whereas when corn was ground into coarser particle size (0.865 mm GMD), there was no difference in energy use when grinding hard or dented corn.

The performance of broilers at 42 days of age was not affected by corn texture or particle size (Table 2), except for production factor, with birds fed hard corn presenting better results (p<0.05) relative to those fed dented corn.

Reece *et al*. (1985), Nir *et al*. (1990) and Nir *et al*. (1994) found higher weight gain and feed intake when broilers were fed coarse particles. Lott *et al*. (1992), working with 3.18 mm and 9.53 mm sieves (GMD = 0.71 mm and 1.17 mm), under temperatures of 15.5 and 26.5 °C, observed reduced weight gain and increase in feed conversion ratio in the birds fed the largest GMD. Parsons *et al*. (2006), working with different corn particle sizes (781, 950, 1042, 1109, and 2242 µm) in diets for 22- to 42-day-old broilers, observed higher feed intake and worse feed efficiency when birds were fed coarser corn particles.

There was no effect of corn texture or particle size on the carcass parameters evaluated when birds were 42 days of age (Table 4). Carcass yield was not affected by the experimental treatments, which is consistent with the results of Dahlke *et al*., (2001) and López & Baião (2002). However, Ribeiro *et al*. (2002) found that particles coarser than 0.680 mm improved carcass yield, and Parsons *et al*. (2006) obtained linear reduction of breast yield and linear increase in abdominal fat as corn particle size increased.

There was an effect (p<0.05) of the interaction between corn texture and particle size on gizzard percentage (Table 5). Independently of corn texture, broilers fed fine particle size presented lower gizzard percentage. As to particle size, when fine particle size was fed, birds fed dented corn presented higher gizzard percentage than those fed hard corn.

Table 5 – Relative gizzard eight of 42-day-old broilers fed corn with different textures and particle sizes.

Texture	Particle size			Medium
	Fine (0.46mm)	Medium (0.73mm)	Coarse (0.87mm)	
Dented	1.74 Ab	1.97 a	1.87 ab	1.86
Hard	1.25 Bb	1.90 a	1.82 a	1.65
Medium	1.50	1.93	1.84	

Means followed by different capital letters in the same column and small letters in the same row are different (p<0.05) by the test of Tukey.

Parsons *et al*. (2006) observed a linear increase in gizzard percentage as corn particle size increased. Nir

Table 4 – Carcass traits of 42-day-old broilers fed corn with different textures and particle sizes.

Parameters (%)	Particle size (PS)			Texture (T)		p value			CV
	Fine (0.46mm)	Medium (0.73mm)	Coarse (0.87mm)	Dented	Hard	PS	T	PSxT	
[1]Carc, %	71.82	71.85	72.36	72.08	71.94	ns	ns	ns	2.27
[1]H+N., %	6.39	6.28	6.23	6.26	6.34	ns	ns	ns	6.71
[1]Feet, %	4.30	4.32	4.31	4.30	4.32	ns	ns	ns	6.78
[1]AbF, %	1.96	2.01	1.5	1.89	1.99	ns	ns	ns	24.36
[2]Breast, %	37.91	37.47	37.37	37.61	37.56	ns	ns	ns	4.40
[2]Leg, %	31.96	32.28	32.37	32.24	32.16	ns	ns	ns	3.87
[2]Wing, %	10.72	10.76	10.74	10.75	10.74	ns	ns	ns	4.20
[2]Back,%	19.66	19.84	19.85	19.74	19.82	ns	ns	ns	4.55

1 - Percentual relative to live weight immediately before slaughter. Carc, carcass yield; H+N, head+neck yield; AbF, abdominal fat percentage; Leg, thigh+drumstick.

et al. (1994) found that gizzard weight of broiler fed finely-ground grains was lower, and their gastric pH higher than those of birds fed coarser particles, and the authors argue that these physiological phenomena influence bird performance. Scholtyssek *et al*. (1983) and Munt *et al*. (1995) found that gizzard weight increases about 1% relative to carcass weight when whole cereal grains are fed.

In the study of Dahlke *et al*. (2001), particle size and feed physical form did not influence carcass yield or leg yield of 42-day-old broilers. The leg yield results obtained in the present study are different from those found by Ribeiro *et al*. (2002), who used mash diets with particle sizes of 0.337, 0.574, 0.680, 0.778, 0.868, and 0.936 mm and observed lower leg yield when particle size was 0.337 mm.

Corn texture did not influence (p>0.05) organ morphometrics of 22- and 41-day-old broilers (Table 6). However, there was an effect of corn particle size (p<0.05) on the relative weight of the gizzard + proventriculus of 22-day-old birds (Table 6). The broilers fed the fine particle size corn presented reduced gizzard + proventriculus weight (p<0.05), possibly due to the lower activity relative of these organs to the other tested particle sizes, as well as lower liver weight (p<0.05) relative to medium particle size. These results are consistent with the findings of Dahlke *et al*. (2003), who observed a linear increase in gizzard weight with increasing corn particle size (0.336, 0.585, 0.856, 1.120 mm). Diets with fine particles flow faster from the stomach to the duodenum and other parts of the small intestine. This faster passage produces marked atrophy of the gizzard and discrete hypertrophy of the small intestine (Nir *et al*., 1994).

Table 6 – Relative organ weights and small and large intestine lengths of 42-day-old broilers fed diets containing hard or dented corn with fine, medium or coarse particle sizes.

	Pro+gizz[1]	Panc[1]	Liv[1]	SI[1]	LI[1]	Length[1]
22 days of age						
Particle size (PS)	0.015	ns	0.027	ns	ns	ns
Fine (0.46mm)	3.02b	0.27	2.50b	3.72	1.04	152.87
Medium (0.73mm)	3.46a	0.30	3.02a	3.68	1.18	152.50
Coarse (0.87mm)	3.53a	0.29	2.63ab	3.56	0.83	148.75
Texture (T)	ns	ns	ns	ns	ns	ns
Dented	3.46	0.30	2.78	3.73	1.00	153.92
Hard	3.22	0.27	2.66	2.58	1.03	148.83
Interaction TxPS	ns	ns	ns	ns	ns	ns
CV (%)	10.3	16.4	13.3	8.8	37.1	5.7
41 days of age						
Particle size (PS)	ns	ns	0.034	ns	ns	ns
Fine (0.46mm)	2.01	0.17	1.70 b	2.17	0.74	193.12
Medium (0.73mm)	2.22	0.18	1.89 ab	2.03	0.78	186.62
Coarse (0.87mm)	2.27	0.18	1.95 a	2.03	0.67	192.00
Texture (T)	ns	ns	ns	ns	ns	ns
Dented	2.14	0.18	1.86	2.05	0.72	192.58
Hard	2.19	0.18	1.84	2.10	0.74	188.58
Interaction TxPS	ns	ns	ns	ns	ns	ns
CV (%)	11.5	15.1	10.0	9.7	23.5	7.3

1 - Pro+gizzard, proventriculus+gizzard; Panc, pancreas; Liv, liver; SI, small intestine; LI, large intestine; Length, length of the small and large intestine (cm). Means followed by different capital letters in the same column are different (p<0.05) by the test of Tukey.

López & Baião (2004) evaluated the physical form of broiler diets, and found lighter livers in birds fed mesh diets as compared with those fed granulated-expanded diets.

There was no influence of corn texture or particle size on the relative weight of the pancreas of 22- or 41-day-old broilers, as opposed to Engberg *et al*. (2002), who observed that broilers fed mash diets with coarse particle size presented heavier pancreas than those fed mash diets with medium particle size.

There was no interaction (p>0.05) between corn texture and particle size for CDMD, NB, nitrogen intake (NI) or nitrogen excretion (NE) (Table 7). Birds fed dented corn presented the highest nitrogen excretion (p<0.05) (Table 7).

Table 7 – Coefficient of dry matter digestibility (CDMD), nitrogen balance (NB), nitrogen intake (NI) and nitrogen excretion (NE) of broilers during the periods of 19 to 22 and 38 to 41 days of age fed diets containing hard or dented corn with fine, medium or coarse particle sizes.

	CDMD, %	NB, g	NB, %	NI, g	NE, g
19 to 22 days of age					
Particle size (PS)	ns	ns	ns	ns	ns
Fine (0.46mm)	71.35	32.90	61.83	53.28	20.38
Medium (0.73mm)	71.31	28.00	57.64	48.00	20.01
Coarse (0.87mm)	72.80	28.10	57.50	48.30	20.21
Texture (T)	ns	ns	ns	ns	0.001
Dented	70.83	30.80	57.49	52.93	22.13A
Hard	72.80	28.25	60.48	46.80	18.26B
Interaction TxPS	ns	ns	ns	ns	ns
CV (%)	4.85	22.88	9.71	14.81	11.33
38 to 41 days of age					
Particle size (PS)	ns	ns	ns	ns	ns
Fine (0.46mm)	73.12	15.38	55.78	27.30	11.91
Medium (0.73mm)	70.00	12.38	48.76	25.06	11.98
Coarse (0.87mm)	72.33	14.90	54.18	27.82	12.92
Texture (T)	0.045	ns	ns	ns	0.001
Dented	69.36B	14.50	49.43	28.85	13.90A
Hard	74.21A	13.95	56.34	24.60	10.65B
Interaction TxPS	ns	ns	ns	ns	0.001
CV (%)	7.70	29.48	16.29	18.64	11.69

Means followed by different letters in the same column are different (p<0.05) by the test of Tukey.

Corn texture affected CDMD during the period of 38 to 41 days of age, with hard corn promoting higher CDMD relative to dented corn (Table 7). The better CDMD and nitrogen excretion results obtained with hard corn during the period of 38 to 41 days of age may explain the better, although not significant, performance of these birds (Table 2). There was en effect of the interaction between corn texture and particle size on nitrogen excretion during the period of 38 to 41 days of age (p<0.05) (Table 8). Birds fed dented corn with coarse particle size presented higher nitrogen excretion. On the other hand, the particle size of hard corn did not influence nitrogen excretion. Considering medium and coarse particle sizes, dented corn presented higher nitrogen excretion than hard corn. However, when ground to fine particle size, corn texture did not affect nitrogen excretion.

Cantarelli *et al*. (2007) observed better nitrogen balance with dented corn relative to hard corn in pigs fed different corn hybrids (high-oil corn, QPM corn, dented corn, semi-dented corn, and hard corn), differently from the results of the present study, indicating different digestibility of corn texture in different animal species. According to Ribeiro *et al*. (2002), different corn particle sizes (0.337, 0.574, 0.680, 0.778, 0.868 and 0.936 mm GMD) had no effect on nitrogen retention in growing broilers, whereas Parsons *et al*. (2006) observed a linear increase in nitrogen retention inf 28-day-old broilers fed different corn particle sizes (781, 950, 1042, 1109, 2242 µm).

Table 8 – Details of the interaction between corn particle size and texture for nitrogen excretion in broilers during the period of 38 to 41 days of age.

Texture (T)	Particle size (PS)		
	Fine (0.46mm)	**Medium (0.73mm)**	**Coarse (0.87mm)**
Dented	11.83 b	13.56 Ab	16.31 Aa
Hard	11.99	10.41 B	9.55 B
CV (%)	11.69	11.69	11.69

Means followed by different capital letters in the same column and small letters in the same row are different (p<0.05) by the test of Tukey.

CONCLUSIONS

Corn with fine particle size promotes better performance of broilers at 21 days of age. Hard corn results in higher dry matter digestibility and lower nitrogen excretion, and consequently higher production factor in 42-day-old broilers.

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