Revista Brasileira de Zootecnia

ISSN 1516-3598 (impresso)
ISSN 1806-9290 (*on-line*)
www.sbz.org.br

R. Bras. Zootec., v.38, n.9, p.1757-1761, 2009

Evaluation of different corn textures in dry grain or silage forms for piglets from 7 to 15 kg[1]

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ABSTRACT - The objective of this study was to evaluate different textures and storage forms of corn in piglet diets. Two experiments were conducted, one of which tested digestibility of nutrients and the other diet performance. In the digestibility trial, 24 crossbred (Landrace × Large White) barrows with an initial weight of 18.7 ± 1.5 kg were used. They were kept in metabolic cages in a randomized block design using the factorial arrangement 2 × 2 (type of corn - dent and flint × type of storage – moist grain silage and dry grain) and six replicates, with one animal as the experimental unit. The values of metabolizable energy (ME) obtained were 3841 kcal of ME/kg of dry matter (DM) from dry corn, 3912 kcal of ME/kg of DM from moist corn, 4022 kcal of DM from ensiled dry corn and 3928 kcal of ME/kg of DM from ensiled humidity corn. The ensilage process increases the digestibility coefficient of dry matter and crude protein and increases the digestible energy of the diets, independent of the process form. The type of corn did not influence these variables. In the performance trial, 60 barrows (initial weight of 6.5 ± 1.5 kg) of the same stock were used during 28 days of post-weaning distributed in the same experimental design, with five replicates and three animals as the experimental unit. The treatments did not influence the daily weigh gain or the daily feed intake. The dentate corn and the ensilage process decreased the feed conversion of the independent form (no significant interaction). The substitution of dry for ensilage corn increased the digestibility of the nutrients in the diets and the feed conversion of the piglets from 7 to 15 kg. Dentate corn promotes best feed conversion in this phase.

Key Words: digestibility, ensilage, nursery phase, nutrition, performance, swine

Avaliação dos milhos dentado e duro fornecidos em forma de grãos secos e de silagem de grãos úmidos para leitões dos 7 aos 15 kg

RESUMO - Objetivou-se com este estudo avaliar os efeitos do tipo de milho (duro e dentado) e da forma de armazenamento (grãos secos ou silagem de grãos úmidos) no valor nutricional das rações e no desempenho de leitões dos 7 aos 15 kg. No ensaio de digestibilidade, utilizaram-se 24 leitões machos castrados (peso inicial de 18,7 ± 1,5 kg), mestiços Landrace × Large White, mantidos em gaiolas de metabolismo em delineamento de blocos casualisados em esquema fatorial 2 × 2, com seis repetições, considerando um animal por parcela experimental. Os valores de energia metabolizável (EM) obtidos foram: 3.841 kcal de EM/kg de matéria seca (MS) para o milho seco; 3.912 kcal de EM/kg de MS para o milho úmido; 4.022 kcal de EM/kg de MS para o milho ensilado seco; e 3.928 kcal de EM/kg de MS para o milho ensilado úmido. O processo de ensilagem do milho melhorou os coeficientes de digestibilidade da matéria seca e da proteína bruta e a energia digestível das rações, independentemente da forma de armazenamento, ao passo que os tipos de milho não influenciaram essas variáveis. No ensaio de desempenho, foram utilizados 60 leitões (peso inicial de 7,3 ± 1,2 kg) machos castrados, também mestiços Landrace × Large White, mantidos durante 28 dias na creche, em mesmo delineamento, porém com cinco repetições e três animais por unidade experimental. O tipo de milho e a forma de armazenamento não influenciaram o ganho de peso e o consumo de ração. O milho dentado e o processo de ensilagem melhoraram a conversão alimentar de forma independente (interação não-significativa). A substituição do milho seco pela silagem de grãos úmidos melhora a digestibilidade dos nutrientes das rações e a conversão alimentar de leitões dos 7 aos 15 kg; além disso, o milho dentado promove melhor conversão alimentar nesse período.

Palavras-chave: desempenho, digestibilidade, fase inicial, milho ensilado, nutrição, suínos

Received December 1, 2006 and accepted November 11, 2008.
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Introduction

Corn is one of the most important feeds in the diet of pigs in Brazil, as it represents about 70% of their diets. However, the types of corn usually marketed in this country have variable chemical compositions and physical properties that directly affect nutritional value. Nutritional value may also be affected by the way corn is stored (Coors et al., 1999).

Corn grains are composed of pericarp, endosperm and embryo. The pericarp is rich in fiber, the endosperm has significant amounts of protein and starch, and the embryo is rich in protein and oil (Watson, 1987). However, the hybrids and varieties of corn in Brazil have different quantities of these nutrients, which varying according to climatic conditions and soil type (Corrêa, 2001).

Moist grain silage is a form of storage used by producers because, in addition to lower costs of production during the season, it can result in a feed of better nutritional value compared to dry corn (Coors et al., 1999). Fornasieri Filho (1992) used the texture of the endosperm to describe corn vitriosity and to classify corn as flint, semi-flint, semi-dent and dent. The classification is determined by protein molecular structure and starch molecular structure, particularly in the pericarp. Depending upon the combination, the starch in the protein may be unavailable or only partially available to young pigs, in which the activities of digestive enzymes are lower (Lima, 2001). However, the process of wet corn silage can reduce this effect and facilitate the activities of digestive enzymes, making the nutrients more available for absorption. Wet corn silage therefore can improve the nutritional value of ensiled grain.

In this study, it was evaluated the nutritional values of diets containing flint and dent corn in the form of dry grain or wet silages for piglets in the initial phase.

Materials and Methods

Two experiments, one for digestibility of nutrients and the other for performance, were carried out in the Departamento de Zootecnia of Universidade Federal de Lavras (UFLA), Lavras, southern Minas Gerais, in Brazil.

Two corn hybrids (flint and dent) were used in both experiments. They were grown at the same location and under the same climatic and agronomic conditions. After reaching the point of physiological maturity (moisture between 28% and 32%), the grains were collected by conventional combine and kept in a clean area. Corn was properly covered with canvas for 24 hours for moisture standardization. Part of the corn was ground in a mill with a 2-mm sieve, and wet cornmeal obtained from each variety was ensiled in 35-kg PVC silos under cylindrical compression for a period of 35 days. The rest of the corn was kept clean with approximately 87% dry matter and stored in silos at the factory to feed the farm. Before its use in feeding, both varieties of non-corn silage were crushed in the mill with a 2-mm sieve.

In the digestibility assay, it was used 24 Landrace × Large White barrows with an initial weight of 18.7 ± 1.5 kg, housed individually in cages and with similar metabolisms to those described by Pekas (1968) and adapted according to methodology reported by Sales et al. (2003). They were housed in a room with air conditioning to control the temperature (20.0 ± 1.5 ºC).

The experimental period lasted for 11 days, divided into 7 days of adaptation to the animal cages and experimental diets and 4 days for total collection of feces and urine.

The experimental design was in randomized 2 × 2 factorial blocks (type of maize - dent and flint - × type of storage – moist grain silage and dry grain) with six replicates and one animal per experimental unit. The blocks were formed according to the weights of the animals.

The diets were formulated using corn, soybean meal and modified milk powder and supplemented with vitamins and minerals in accordance with the recommendations of Rostagno et al. (2005) (Tables 1 and 2).

The diets containing corn in the form of dry grain were mixed all at once at the beginning of the experiment, while those with grain moisture silages were mixed daily in the late afternoon. All animals were provided feed based on metabolic weight ($BW^{0,75}$) adjusted by the lower consumption of animal intake during the adjustment period. The amount calculated for each animal was divided into two equivalents and offered at 8 and 16 h. Water was provided ad libitum throughout the experimental period. To determine the beginning and end of collection, ferric oxide (Fe_2O_3) was used as a fecal marker.

Feces were collected daily, placed in plastic bags and kept in a freezer (-10 ºC) prior to analysis. Urine was collected daily in plastic buckets with filtration for retention of dirt and 20 mL hydrochloric acid (HCl 0.25 N) to avoid possible loss of nitrogen resulting from the proliferation of microorganisms. To standardize the volume of urine obtained from all animals, water was added to bring the collection to 2,000 mL/day for each animal. Of this total, an aliquot of 200 mL was removed, conditioned in bottles and kept in a freezer (-10 ºC) prior to analysis. At the end of

Table 1- Nutritional composition of the ingredients experimental diet[1]

Ingredient	Dry dent corn	Dry flint corn	Ensilage dent corn	Ensilage flint corn	Soybean meal	Modified milk powder
Dry matter (%)[2]	87.2	87.1	67.3	70.4	88.2	94.7
Crude protein (%)[2]	9.97	10.06	9.41	8.72	51.7	17.55
Crude fiber (%)[2]	1.54	1.77	1.91	1.73	6.21	-
Calcium[2]	0.03	0.03	0.03	0.03	0.27	0.79
Phosphorus (%)[2]	0.27	0.27	0.28	0.27	0.2	0.72
Lysine (%)	0.32[3]	0.28[3]	-	-	2.78	0.95
Methionine (%)	0.21[3]	0.17[3]	-	-	0.67	0.19
Threonine (%)	0.26[3]	0.27[3]	-	-	1.76	0.68

[1] Values expressed in dry matter.
[2] Values from Animal Research Laboratory of UFLA.
[3] Values from Cantarelli (2003).

Table 2 - Composition of experimental diets

Item	Dry dent corn	Dry flint corn	Ensilage dentate corn	Ensilage flint corn
Dry corn	54.40	54.40	-	-
Moist grain silage	-	-	54.40	54.40
Soybean meal	32.40	32.40	32.40	32.40
Modified milk powder	6.20	6.20	4.80	4.80
Soybean oil	3.60	3.60	5.00	5.00
Dicalcium phosphate	1.50	1.50	1.50	1.50
Limestone	0.57	0.57	0.57	0.57
Sal t	0.40	0.40	0.40	0.40
DL-methionine 99	0.08	0.08	0.08	0.08
L-threonine 98,5%	0.11	0.11	0.11	0.11
L-lysine HCl 78%	0.35	0.35	0.35	0.35
Vitamin mix[1]	0.10	0.10	0.10	0.10
Mineral mix[2]	0.10	0.10	0.10	0.10
Antibiotic[3]	0.10	0.10	0.10	0.10
Antioxidant	0.10	0.10	0.10	0.10
Nutritional (analyzed)				
Dry matter (%)[4]	88.22	88.25	80.26	80.55
Crude protein (%)[4]	23.66	23.70	23.98	23.91
Digestible energy (kcal/kg)[5]	3912	3841	3928	4022
Digestible lysine (%)[5]	1.440	1.440	1.440	1.440
Digestible methionine (%)[5]	0.745	0.745	0.745	0.745
Digestible threonine (%)[5]	1.145	1.145	1.145	1.145
Digestible triptophan (%)[5]	0.681	0.681	0.681	0.681

[1] Composition/kg of product: vit. A, 8,000,000 UI; vit. D3, 1,200,000 UI; vit. E, 20 g; vit. K3, 2.5 g; vit. B1, 1 g; riboflavin (B2), 4 g; piridoxine (B6), 2 g; vit. B12, 20 cg; niacin, 25 g; pantothenic acid, 10 g; folic acid, 600 mg; biotin, 50 mg; vit. C, 50 g; antioxidant, 125 mg.
[2] Composition/kg of product: selenium, 500 mg; Fe, 70 g; Cu, 20 g; Mn, 40 g; Zn, 80 g; I, 800 mg; Co, 500 mg.
[3] Granulated tylosine.
[4] Values from Animal Research Laboratory of UFLA.
[5] Values from Rostagno et al. (2005).

the collection, the feces and urine were homogenized for use in laboratory tests. The other method procedures followed those described by Fialho et al. (1979).

The contents of dry matter, crude protein and energy in the diets, feces and urine were determined in the laboratory according to methodology described by AOAC (1995). It was analyzed the coefficient of digestibility of dry matter, crude protein, digestible energy and gross energy of diets.

In the performance experiment, 60 weaned, castrated male and female piglets with an initial weight of 7.3 ± 1.2 kg were used. They were housed in brick rooms in a nursery hall in groups of three, and kept in pens (2.00 × 1.20 m) equipped with semi-automatic feeders and drinker-type pacifiers for 28 days. The temperature was controlled with heating lamps and fans. Before housing the animals, the room was properly cleaned, disinfected and maintained fallow for a minimum period of seven days.

The same experimental design was used in this experiment as that in the digestibility experiment; however, there were five replicates and three animals per pen.

The diets were given ad libitum after weighing. The diets containing moist grain silage were mixed daily in the afternoon and delivered to animals after cleaning the feeders. All orts were weighed to determine actual animal consumption. During the experimental period, water was provided ad libitum.

The animals were weighed at the beginning and at the end of the experimental period to determine feed effects on weight gain.

The average daily gain, average daily feed intake and feed effect on gain were analyzed. All data were submitted to variance analysis using the statistical package SISVAR described by Ferreira (2000).

Results and Discussion

The minimum and maximum temperatures recorded during the experiment were 24.5 ± 1.4 ºC and 28.1 ± 1.8 ºC, respectively, and were above the term neutrality zone, which is 20 to 22 ºC (Lima et al., 1999).

There were no interactions (P>0.05) between corn types and forms of storage for the coefficients of digestibility of dry matter, crude protein, digestible energy and gross energy of diets (Table 3). The process of corn silage increased the digestibility coefficients of dry matter and crude protein and the digestible energy of diets (P<0.05). Similar results were obtained by Silva et al. (2005) for the coefficients of digestibility of dry matter and crude protein, but these authors observed lower values for digestible energy in animal experiments in growth-fed diets containing moist grain silage or dry ration.

The results obtained for digestible energy and the digestibility of dry matter and crude protein were higher than those observed by Oliveira et al. (2004). This increase may be related to the process of ensiling, which provides a favorable environment for the formation of organic acids produced during the fermentation process. These acids can cause ruptures in the structures covering the granules of starch, gelatinization of starch and partial opening of the pore structure of granules, favoring animal digestive processes (Lopes, 2000).

The type of corn did not influence the average daily gain, average daily feed intake or feed: gain ratio of the piglets (P>0.05) (Table 4). There were no effects of the type of corn or the form of storage on the average daily gain and average daily feed intake (P>0.05). Similar responses were found by Oliveira et al. (2004) when assessing levels of substitution of dry corn for moist grain silage for piglets in the initial phase.

Despite these results, feed conversion improved with the supply of dent corn compared to flint corn, regardless of whether the corn was provided in the dry grain form or moist grain silage (P<0.05). The interaction of corn type and storage form was not significant (P>0.05). This is probably due to the percentage of vitreous endosperm in dent corn (Cantarelli et al., 2007), which may have interfered directly in the digestive process of piglets.

Table 3 - Digestibility of dry matter, crude protein and energy in diets containing flint corn or dent corn in the form of dry grain or moist grain silage

Item	Dry grain	Moist grain silage	Mean
Dry matter			
Flint corn	85.15	86.98	86.07
Dent corn	86.43	87.05	86.74
Mean	85.79b	87.01a	
Crude protein (%)[1]			
Flint corn	85.35	90.03	87.67
Dent corn	86.31	89.03	87.69
Mean	85.83b	89.53a	
Gross energy (%)[2]			
Flint corn	86.77	86.27	86.52
Dent corn	85.49	86.88	86.41
Mean	86.13	86.57	
Digestible energy (kcal/kg)[1]			
Flint corn	3841	4022	3931
Dent corn	3912	3928	3920
Mean	3876b	3975a	

[1] Means followed by different letters differ by F test (P<0.05).
[2] Non-significant by F test (P>0.05).

Table 4 - Performance of piglets in the period from 1 to 28 days post-weaning fed diets containing flint corn or dent corn in the form of dry grain or moist grain silage

Item	Storage form		Mean
	Dry	Moist grain silage	
	Average daily feed intake (g of DM/day)[1]		
Flint corn	587	562	574
Dent corn	580	556	568
Mean	583	559	
CV (%)	14.4		
	Average daily gain (g/day)[1]		
Flint corn	286	299	292
Dent corn	310	311	310
Mean	298	305	
CV (%)	12.5		
	Feed:gain[2]		
Flint corn	2.05	1.87	1.96b
Dent corn	1.87	1.78	1.82a
Mean	1.96b	1.82a	
CV (%)	5.5		

[1] Non-significant by F test (P>0.05).
[2] Means followed by different capital letters in the column and small letters in the row differ by F test (P<0.05).

In addition, the ensiling process of corn improved the feed conversion of the animals, regardless of the type of corn used. These results are similar to those reported by Tófoli et al. (2003) in an experiment using diets with dry corn and moist grain silage. According to these authors, a higher percentage of vitreous endosperm in grains undergoes hydrolysis under the anaerobic conditions in the silo; this may increase the availability of nutrients. Moreover, the formation of organic acids during the process of ensiling may also contribute to the improvement in the feed:gain ratio of piglets.

Several authors have reported positive effects from adding organic acids to the diets of piglets after weaning (Radcliffe et al., 1998; Omogbenigun et al., 2003). According to Holmes et al. (1974), increasing the total acidity of the diet and diets with the inclusion of wet corn promote better nutrient retention, better digestibility of protein in the stomach, and more uniform flow of digest into the small intestine. Moreover, the low-pH environment is responsible for a reduction in the number of pathogenic microorganisms, which may improve the performance of animals in the post-weaning period.

Conclusions

The replacement of dry flint corn or dent corn with moist grain silage improves the digestibility of nutrients in the diet and provides a better feed: gain ratio for piglets from 7 to 15 kg. Dent corn improves feed conversion relative to flint corn.

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