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ANIMAL PRODUCTION

High-moisture sorghum grain silage with low- and high-tannin contents for weanling piglets

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ABSTRACT: *Sorghum is the second cereal used in pigs' diets in Brazil, which has a lower cost than corn, thus this experiment aimed to study the effects of high-moisture sorghum silage grain with high- and low-tannin contents on silage quality and piglets' performance. A total of seventy-two weaned piglets were allocated into randomized blocks with six replicates and four treatments, based on diets with dry corn grain (DCG); dry sorghum grain with low-tannin (LTSG), high-moisture sorghum grain silage with low-(LTSS) and high-tannin (HTSS). The ensiling process decreased total and condensed tannin contents to 31% and 98% for LTSS and, to 80% and 93% for HTSS, respectively. No treatment effects observed on average daily feed intake and average daily weight gain. The feed:gain ratio of piglets fed LTSS was greater than piglets fed LTSG. At total period, piglets fed HTSS showed a similar feed:gain ratio than piglets fed DCG or LTSG, although it was worse than animals fed LTSS. The LTSS and HTSS can replace corn or sorghum dry grains in diets of weanling pigs with no adverse effects on growth performance.*
Key words: *ensiling process, performance, pigs, sorghum grain.*

Silagem de grãos úmidos de sorgo com alto e baixo tanino para leitões recém-desmamados

RESUMO: *O sorgo é o segundo cereal mais utilizado nas dietas de suínos no Brasil e possui menor custo em relação ao milho. Neste contexto, este experimento objetivou estudar os efeitos da silagem de grãos úmidos de sorgo baixo e alto tanino na qualidade da silagem e desempenho de leitões. Utilizaram-se 72 leitões na fase de creche alocados em blocos ao acaso, com quatro tratamentos e seis repetições. Os tratamentos foram dietas à base de grãos de milho seco (M), grãos de sorgo seco baixo tanino (SSBT), silagem de grãos úmidos de sorgo com baixo (SBT) ou alto tanino (SAT). A ensilagem reduziu os teores de taninos totais e condensados em 31% e 98% para a SBT e, em 80% e 93% para a SAT, respectivamente. Não houve efeito dos tratamentos no consumo diário de ração e ganho diário de peso. A conversão alimentar dos leitões que receberam SBT foi melhor que a daqueles alimentados com dietas com SSBT para os períodos estudados. No período total, os leitões que receberam dietas com SAT apresentaram conversão alimentar semelhante àqueles alimentados com dietas com M ou SSBT, porém pior que aqueles alimentados com dietas com SBT. As SBT e SAT podem substituir o milho seco e o sorgo seco baixo tanino das rações sem prejuízo ao desempenho de leitões na fase de creche.*
Palavras-chave: *desempenho, ensilagem, grãos de sorgo, suínos.*

INTRODUCTION

Sorghum has composition and nutritional value variable depending on the presence and concentration of tannins, which are phenolic compounds of high molecular weight that compromise palatability; reduced digestibility, particularly of protein and starch, interfering with minerals and vitamins absorption and retention (SCHOFIELD et al., 2001).

Indeed, feedstuffs that commonly are used in preparing diets for animals can be subjected to several processing forms, in order to inactivate or destroy any antinutritional factors and thus, improve digestibility. The ensiling process of sorghum grain (***Sorghum bicolor*** (L.) Moench) is an economically feasible practice to reduce considerably tannins and other antinutritional factors. Thus, dry sorghum grain with low-tannin is a great option to pig feeding, since it has similar nutritional composition and provides similar performance as corn (PATRÍCIO et al., 2006). Besides its agronomic advantages, such as early-harvest and release of area for other crops, the use of high-moisture silage has improved performance and it has reduced diarrhea prevalence in piglets at nursery phase (LOPES et al., 2001a) and on performance of growing and finishing pigs compared to animals fed dry corn (LOPES et al., 2001b).

Whereas in technified swine production, piglets are early-weaned at a moment that they have low stomach's ability to produce HCl and

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enzymatic secretion for starch digestion, contributing to its digestive immaturity (CHAMONE, 2010), the acidification of diets favored by ensiling, contributed to the improvement of sows and piglets' performance, since organic acids are utilized in diets preservation in order to stabilize pH and reduce buffering capacity (LEHNEN et al., 2011) and also, presents antimicrobial and immunomodulating action (TSILOYIANNIS et al., 2001), leading to a better digestibility and nutrient absorption by increasing gastric-retention time of digesta (MROZ, 2005).

Therefore, as sorghum is the second cereal used in pigs' diets in Brazil, which has a lower cost than corn, this experiment aimed to study the effects of high-moisture sorghum grain silage with high- and low-tannin contents on silage quality and piglets' performance.

MATERIALS AND METHODS

Production of silages

The sorghum grain with low- or high-tannin contents were harvested at 29.33% and 29.50% of moisture levels, respectively, then grounded and ensiled within 100-L polyvinyl chloride cylindrical silos. The temperature inside silos was monitored and registered throughout 30 days with T-type copper (+)/constantan (-) thermocouple, isolated in PVC, wire diameter of 0.5mm coupled to data loggers that recorded readings at intervals of 10-sec, and averages every 2-hour. The system also registered the ambient temperature where the silos were stored. For production of high-moisture sorghum grain silage with low-tannin and dry sorghum grain with low-tannin, the same variety of sorghum was utilized harvested at different moisture levels.

Chemical analyses of silages

Chemical compositions of dry corn (DCG), dry sorghum with low-tannin (LTSG) and high-tannin (HTSG) and, high-moisture sorghum grain silages with low- (LTSS) and high-tannin (HTSS) are shown in table 1. At the end of ensiling process, silages were sub-sampled for pH analysis (CHERNEY & CHERNEY, 2003), moisture (AOAC, 1984) and particle size quantifications (ZANOTTO & BELLAVER, 1996).

Samples for LTSS and HTSS organic acids determinations were centrifuged at 12,000rpm for 8-min. Then, it was filtered through a polyvinylidene fluoride membrane (PVDF) of 0.22µm pore size and 13mm diameter (Millipore®, Cork, Ireland) for retaining solid content, according to MUCK & DICHERSON (1988). The supernatant was injected by an automatic sampler into a chromatograph (Varian, model ProStar 410, Santa Clarita, CA) coupled to a refractive index detector with column Bio-Rad Aminex HPX-87H (Bio-Rad Laboratories, Hercules, CA, USA) at 65°C and flow rate of 0.6mL/min for a total time of 35-min.

Samples of dry sorghum grain and high-moisture sorghum grain silages were analyzed for total and condensed tannins at Center of Nuclear Energy in Agriculture, Universidade de São Paulo, Piracicaba, Brazil. An amount of 200mg of ground samples (0.25mm) were transferred into beckers, adding 10-mL of 70% acetone solution, then ultrasound-extracted for 20-min in water with ice cubes and centrifuged at 4°C for 10-min at 3,000*x g*. The supernatant (extract) was collected and stored on ice.

For total tannin analyses, 100mg of polyvinylpolypyrrolidone (PVPP) was weighed in a test tube, adding 1-mL of distilled water and 1-mL of diluted extract. After mixing, tubes were kept in cold storage for 15-min and mixed again. Then, tubes were centrifuged at 3,000*x g* for 10-min at 4°C and the supernatant collected. From this point on and, with remaining extract, the procedures for determination of total phenols were performed and, from the difference between total phenols and phenol after extraction with PVPP, the total concentration of tannins was obtained. Into tubes were added 0.5-mL of the diluted extract, 3-mL of butanol-HCl reagent and 0.1-mL of ferric reagent, and later on, mixed. Tubes were heated at 100°C for 1-hour in a water bath. A blank of each sample (with and without dilution) was prepared without heating. After this step, tubes were cooled off and readings determined by UV-Vis spectrophotometry, with absorbance at 550nm, obtaining the results of condensed tannins, according to WATERMAN & MOLE (1994).

Performance evaluation

The performance trial was carried out in swine production experimental area at Universidade Estadual Paulista, Botucatu, Brazil. A total of 72 piglets, females and castrated males of commercial lineage (Landrace x Large White) with an average initial weight of 7.11±0.76kg, weaned at an average age of 23 days were housed in a nursery facility with a ceiling height of 3.5m, side curtains and suspended metal pens of 1.75m^2 equipped with one feeder, one nipple-type drinker and one heater during initial phase. Pens had a partially slatted plastic flooring and a compact concrete floor under the heater. Internal temperature of nursery

Table 1 - Chemical composition (values expressed on dry matter basis), geometric mean diameter values (GMD), pH and moisture levels of DCG, LTSG, HTSG, LTSS and HTSS; the organic acids profiles of LTSS and HTSS; total and condensed tannin percentages of LTSG, LTSS and HTSS used in performance trial.

Analyses	DCG*	LTSG*	HTSG*	LTSS*	HTSS*
CP (%)	9.53	12.18	9.66	12.06	9.00
CF (%)	5.11	3.05	1.90	3.76	2.85
Minerals (%)	1.01	1.34	1.42	1.53	1.35
NFE (%)	81.75	80.30	83.67	79.90	84.37
CF (%)	2.60	3.13	3.35	2.75	2.43
GMD (µm)	653	525	-	1,062	1,116
pH	5.77	6.20	-	3.80	4.00
Moisture (%)	11.03	12.08	12.12	29.33	29.50
Total organic acids (% DM)	-	-	-	0.94	1.20
Lactic (%)	-	-	-	59.92	76.40
Acetic (%)	-	-	-	15.44	8.30
Propionic (%)	-	-	-	23.74	13.09
Butyric (%)	-	-	-	0.90	2.21
Total tannins (%)	-	0.55	1.51	0.38	0.31
Condensed tannins (%)	-	0.48	1.17	0.01	0.08

*DCG = dry corn grain; LTSG = dry sorghum with low-tannin; HTSG = dry sorghum with high-tannin; LTSS = high-moisture sorghum grain silage with low-tannin; HTSS = high-moisture sorghum grain silage high-tannin.

facility was controlled by adjustment of side curtains and management of heaters.

The experimental design was a randomized block assay with four treatments and six replicates. The criteria considered for blocks formation was weight, sex and litter. To each experimental unit (three animals) was randomly attributed the following treatments: diets based on dried corn grain (DCG); diets based on dry sorghum grain with low-tannin (LTSG); diets based on high-moisture sorghum grain silage with low-tannin (LTSS) and diets based on high-moisture sorghum grain silage with high-tannin (HTSS).

Throughout the experimental period (30 days), piglets were fed *ad libitum* within a phase feeding program to attend its nutritional requirements, in accordance with ROSTAGNO et al. (2005), except for crude protein and digestible energy, in the following phases: pre-starter diet I (0 to 8^{th} day), pre-starter diet II (from 9^{th} up to 20^{th} day) and starter diet I (from 21^{st} to 30^{th} day) (Table 2). Dry matter (DM) contents of silages were adjusted for the same DM of correspondent dry sorghum grain using correction factors for replacement of dry sorghum grain by silages in diets. To determine the weight gain results, piglets were weighed at the beginning, at the 8^{th} and at 30^{th} experimental days. Feed intake was calculated at each phase, by the difference between the amount of feed provided and the amount of leftovers. The animals had free access to water and all data were submitted to analysis of variance by PROC GLM procedure of SAS (2001), and averages compared by Tukey's test (P<0.05).

RESULTS AND DISCUSSION

The geometric mean diameter (GMD) of particles of high-moisture sorghum grain silage was on average 100% higher than dry sorghum particles (Table 1). The GMD value of dry sorghum particles (525µm) was lower than dry corn particles (653µm), despite grinding of these cereals can be considered appropriate, results of experiments with pigs in the following phases: initial, growing, finishing and lactating have indicated that best particle size of dry corn and sorghum would be, respectively, ≤600µm and ≤500µm (HEALY et al., 1994; WONDRA et al., 1996).

The pH and organic acids concentrations are important qualitative indicators of ensiling process. The LTSS and HTSS pH values (Table 1) stood close to the range considered the most suitable for conservation of dry grains, which is about 3.8% to 5.0% (LOPES, 2004). The total organic acids content produced was 28% higher for HTSS compared to LTSS (Table 1). The LTSS and HTSS lactic acid

Table 2 - Percentual composition and calculated nutritional values of experimental diets provided to piglets at each phase[1].

Ingredients	------Phase I (0 to 8 days)------			-------Phase II (9 to 20days)-------			-----Phase III (21 to 30days)-----		
DCG	40.00	-	-	55.95	-	-	64.39	-	-
LTSG	-	41.500	-	-	57.95	-	-	64.93	-
HTSG	-	-	38.80	-	-	54.45	-	-	60.93
Soybean meal	20.00	18.50	21.20	23.00	21.00	24.50	27.54	27.00	31.00
Whey	19.70	19.70	19.70	9.90	9.90	9.90	-	-	-
Blood cells[2]	2.58	2.58	2.58	2.35	2.35	2.35	-	-	-
Wheat meal	9.90	9.90	9.90	0,50	0.50	0.50	-	-	-
Sugar	4.00	4.00	4.00	5.00	5.00	5.00	3.00	3.00	3.00
Soybean-oil	-	-	-	-	-	-	1.50	1.50	1.50
Dic. phosphate	1.67	1.67	1.67	1.58	1.58	1.58	1.74	1.74	1.74
Limestone	0.74	0.74	0.74	0.75	0.75	0.75	0.82	0.82	0.82
Salt	0.30	0.30	0.30	0.35	0.35	0.35	0.35	0.35	0.35
Premix[3]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
$CuSO_4$	-	-	-	0.08	0.08	0.08	-	-	-
ZnO 77%	0.29	0.29	0.29	-	-	-	-	-	-
Choline chloride	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
L-Lys.HCl 78%	0.35	0.35	0.35	0.21	0.21	0.21	0.36	0.36	0.36
DL-Met 99%	0.10	0.10	0.10	0.06	0.06	0.06	0.04	0.04	0.04
L-Thr 99%	0.15	0.15	0.15	0.07	0.07	0.07	0.08	0.08	0.08
Antioxidant	0.03	0.03	0.03	0.03	0.03	0.03	-	-	-
Total		100.00			100.00			100.00	
----------Calculated values[5]----------									
DE (kcal kg^{-1})	3,366	3,330	3,219	3,381	3,317	3,174	3,439	3,367	3,207
Crude protein (%)	19.25	19.92	19.73	19.37	20.19	19.97	18.92	20.45	20.23
Ca (%)	0.91	0.91	0.91	0.82	0.82	0.83	0.83	0.83	0.83
Total P (%)	0.66	0.66	0.67	0.62	0.63	0.64	0.62	0.63	0.64
Digestible Lys (%)	1.27	1.22	1.27	1.15	1.09	1.16	1.10	1.07	1.15
Digestible Met (%)	0.33	0.32	0.32	0.31	0.29	0.30	0.30	0.29	0.30
Digestible Thr (%)	0.78	0.76	0.78	0.72	0.68	0.68	0.67	0.66	0.70
Digestible Trp (%)	0.19	0.19	0.20	0.20	0.20	0.21	0.19	0.20	0.21

DCG = dry corn grain; LTSG = dry sorghum with low-tannin; HTSG = dry sorghum with high-tannin[1]The sorghum silage was replaced by correspondent amount of dry sorghum grain in diets based on same dry matter basis. [2]AP-301® (American Protein Corporation). [3]Quantities supplied per kg of diet: 240mg Fe; 7.2mg Cu; 80mg Zn; 48mg Mn; 0.48mg I; vit. A: 15,000I.U.; vit. D3: 1,500I.U.; vit. E: 50mg; vit. K_3: 3mg; vit. B_1: 2.50mg; vit. B_2: 7mg; vit. B_3: 35mg; vit. B_5: 20mg; vit. B_6: 4mg; vit. B_9: 1.5mg; vit. M: 150g; vit. B_{12} 35ug; Se: 300ug. [5]Calculated values based on chemical analysis and average composition of ingredients presented by ROSTAGNO et al. (2005).

concentrations were 0.56% and 0.92% on DM basis, respectively. Similar results were reported by HUCK et al. (1999), that used silage with original moisture grains or reconstituted grains using the same variety of sorghum at different moisture levels (25%, 30% and 35%) and, obtained 0.40%, 1.25% and 1.5% of lactate, respectively. The lactic acid values of silages were similar to those reported by PODKÓWKA & PODKÓWKA (2011), working with corn and sorghum silages. This acid is presented in higher quantities in relation to others, a desirable fact, once its presence favors the occurrence of homolactic fermentation, which prevents DM or energy losses (KUNG et al., 2003).

Moreover, synergistic action of lactic and acetic acids, when in suitable proportions in silage mass compared to other acids, improves the anaerobic stability phase of ensiling process, helping on control of spoilage bacteria, since pH lowering favors the faster change of bacteria profile, reducing proteolysis, protein deamination, promoting the best use of soluble carbohydrates and resulting in an increased retention of silage nutrients (PODKÓWKA & PODKÓWKA, 2011).

Butyric acid levels reported in silages corroborated those found by FARIA JÚNIOR et al. (2011), which reported values between 0.2% to 2.5%, values indicative of good fermentation and preservation of silage since population of ***Costridium*** spp., largest producer of acid in question, probably had its growth inhibited due to pH lowering, ensuring better quality of silage. Regarding acetic and propionic acids, these remained at intermediate levels between the lactic and butyric acids, values that agreed with FRANÇA et al. (2011) study, that used different sorghum hybrids as silage.

The ensiling process reduced total and condensed tannins concentrations, respectively about 31% and 98% for LTSS and, respectively, about 80% and 93% for HTSS (Table 1), which probably occurred due to acidity of medium and the action of microbial population in anaerobic silo environment, that contributed to deactivation of condensed tannins, which in acid medium, depolymerize to low molecular weight compounds. These results agreed with those that had demonstrated a decline on tannin content in HTSS at 20% moisture level (PATRÍCIO et al., 2006). The maximum temperature reached inside silos during anaerobic fermentation process of LTSS (28ºC) and HTSS (25.83ºC) were similar and, the difference on moisture content between silages was only about 0.17%, which may explain the fact that percentage of condensed tannins reduction were close in both silages.

Concerning piglet's performance results, there were no effects of treatments on daily feed intake and daily weight gain at any of studied periods (Table 3), corroborating the observed by PATRÍCIO et al. (2006). However, the feed: gain ratios of piglets fed LTSS was greater ($P<0.05$) compared to those fed dry sorghum at both studied phases. At total period, piglets that received HTSS showed similar feed:gain ratio to those that received dry corn or sorghum, but worse ($P<0.05$) than animals fed LTSS. Results of feed: gain ratio were probably due to reduction on tannin contents occurred during ensiling process, to the lower pH and to the structural changes in endosperm of ensiled grains.

An experiment conducted by MYER et al. (1986) with pigs from 28kg to 98kg reported an improvement of 3% on feed:gain ratio of pigs fed high-moisture sorghum grain silage at 25% moisture level compared to those that received dried grains. Best responses in performance, especially in feed: gain ratios were also verified by OLIVEIRA et al. (2004), TÓFOLI et al. (2006) and, TSE et al. (2006). The variations reported in the feed:gain ratio results may be related to differences on moisture levels of sorghum grains at ensiling time, providing greater or lower reduction on tannin contents and changes in structure of starch granules, as well as on quality of silage produced, that have been attributed to structural changes occurred in endosperm of ensiled sorghum and to the lower pH of diets containing silage.

The silage production process improves starch digestibility of sorghum grains (PATRÍCIO et al., 2006) depending on temperature levels and action of organic acids that occur during ensiling process, since temperature affects microbial growth, as well as enzymatic activity. The organic acids in turn promote breaking points on protein matrix that covers starch granules and in its structure, also acting on starch gelatinization (ROONEY & PFLUGFELDER, 1986), favoring its digestion.

Furthermore, silage provides organic acids that may contribute to reduction of digesta buffering capacity (MROZ, 2005) and assist on piglet's

Table 3 - Average daily gain (ADG), daily feed intake (DFI) and feed:gain ratio (F:G) of piglets fed diets with dry corn (DCG), dry sorghum with low-tannin (LTSG), high-moisture sorghum grain silage with low-tannin (LTSS) or high-tannin (HTSS) during initial phase[1].

	Period (days)	DCG	LTSG	LTSS	HTSS	CV (%)[3]	*P-values*
ADG (g)	0 to 8	412	387	421	420	9.44	0.6409
	0 to 30	571	568	603	583	4.43	0.5501
DFI (g)[2]	0 to 8	575	581	532	567	6.44	0.5631
	0 to 30	1,044	1,100	1,036	1,100	5.79	0.5263
F: G	0 to 8	1.40[ab]	1.52[a]	1.27[b]	1.36[ab]	9.97	0.0352
	0 to 30	1.83[ab]	1.93[a]	1.72[b]	1.88[a]	4.39	0.0209

[1]Values followed by different lower case letters on lines differ by Tukey's test ($P<0.05$).
[2]Values of DFI set to same dry matter basis of dry sorghum.
[3]CV = coefficient of variation.

digestive process, reducing digestion incidence of post-weaning diarrhea syndromes and swelling syndrome in piglets at nursery phase (CHAMONE et al., 2010). In this context, it could be expected that the increase on digestibility of ensiled grains would improve efficiency of feed utilization, resulting in better feed:gain ratios.

CONCLUSION

Ensiling process decreases total tannin and condensed levels in sorghum. The high-moisture sorghum grain silages with low- and high-tannin in piglet's diets at nursery phase are an alternative for replacement of corn or dry sorghum with low-tannin without prejudice to piglets' performance. However, based on feed: gain ratio values, the high-moisture sorghum grain silage with low-tannin has better nutritional value compared to high-moisture sorghum grain silage with high-tannin for weanling pigs.

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BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

The research was performed with approval by The Animal Ethics Committee from this institution (protocol number 102/2015/CEUA) and, in accordance with the directive 86/609/EEC.

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