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SILAGEM DE GRÃO ÚMIDO DE MILHO, RECONSTITUÍDO A PARTIR DO GRÃO SECO EM DIFERENTES SISTEMAS DE SECAGEM, PARA A ALIMENTAÇÃO DE LEITÕES

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RESUMO: A técnica da ensilagem de grãos reumedecidos consiste em devolver ao milho seco a umidade recomendada para que possa ser acondicionado em silos e submetido a processo de fermentação anaeróbica. Entretanto, a reconstituição da umidade do milho que já foi seco pressupõe menor perfil microbiológico e nutricional desse produto. Assim, esta pesquisa objetivou avaliar os efeitos de diferentes sistemas de secagem de milho sobre a qualidade da silagem oriunda de grãos reidratados, bem como, sobre o desempenho de leitões em fase de creche. Os grãos de milho foram colhidos com diferentes teores de umidade e submetidos a diferentes processamentos: naturalmente ensilados, sem a secagem e reumedecimento dos grãos (testemunha) e ensilados após reumedecimento dos grãos secos por diferentes métodos de secagem. Para avaliação da qualidade, foram realizadas análises de pH das silagens e condutividade elétrica dos grãos. O ensaio de desempenho de leitões em fase de creche foi conduzido num delineamento em blocos ao acaso, com quatro tratamentos, cinco repetições. Os resultados indicaram maior efeito deletério para o milho seco em alta temperatura. O ensaio de desempenho animal detectou diferenças entre os tratamentos, em favor da secagem artificial dos grãos, apenas até aos 18 dias de idade dos leitões.

Palavras-chaves: Reidratado, desempenho, silagem.

MOIST CORN GRAIN SILAGE, RECONSTITUTED FROM DRY GRAIN IN DIFFERENT DRYING SYSTEMS, FOR PIGLETS FEEDING

ABSTRACT: The technique of ensiling re-moistened grains consists of returning the recommended moisture to the dry corn so that it can be placed in silos and subjected to an anaerobic fermentation process. However, the reconstitution of moisture in corn that has already been dried presupposes a lower microbiological and nutritional profile of this product. Thus, this research aimed to evaluate the effects of different corn drying systems on the quality of silage from rehydrated grains, as well as on the performance of piglets in the nursery phase. The corn grains were harvested with different moisture contents and submitted to different processing: naturally ensiled, without drying and

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rewetting the grains (control) and ensiled after rewetting the dried grains by different drying methods. To evaluate the quality, analyzes of pH of the silages and electrical conductivity of the grains were carried out. The performance test of piglets in the nursery phase was carried out in a randomized block design, with four treatments, five replications. The results indicated a greater deleterious effect for corn dried at high temperature. The animal performance test detected differences between treatments, in favor of artificial drying of grains, only up to 18 days of age of piglets.

Keywords: Rehydrated, performance, silage.

1 INTRODUCTION

Corn is the main ingredient used in animal diets and is considered an energetic food because it is mainly a source of starch and lipids . The increase in the production of poultry, pigs and cattle in recent years increased the area of the crop, which, in the 2018/19 harvest, reached a planted area of 17,075 hectares and a production of 92,808 tons (CONAB, 2019).

To supply food during the season of forage production, silage, including whole plants, wet grains or rehydrated grains, has been a successful alternative, as it results in greater weight gain and better digestion by the animal than dry corn (HENRIQUE *et al.*, 2007). Operationally, the use of naturally moist grains has several advantages, such as the absence of drying costs, discounts on humidity or impurities, earlier harvesting and better efficiency in the area (COSTA *et al.*, 1999; JOBIM; CECATO; CANTO, 2001).

However, the ideal time for harvesting corn grains for naturally moist grain silage (28% to 35%) is very restricted, in addition to having a decisive effect on the nutritional value of the food (JOBIM; BRANCO; SANTOS, 2003). Thus, the possibility of rehydrating grain that has already been dried can be an interesting alternative for the producer, as he will be able to buy dried corn in times of good supply and lower prices.

On the other hand, the reconstitution of moisture in corn that has already been dried and, eventually, stored for some time presupposes a lower hygienic and nutritional quality of this product, considering greater possibilities of stress and losses during its stay in the field, during cleaning, drying and throughout the storage process (ARCARI *et al.*, 2015).

When the grain drying process is carried out with heated air up to 10 °C above the ambient temperature, the process is called a drying system with natural air or at low temperatures, such as those that occur in the plant, in yards or in drying silos. Moreover, there is a high-temperature drying system that is faster and less dependent on atmospheric conditions, allowing the water content of harvested products to be safely reduced to above 20% humidity. Some care must be taken when operating these dryers, as the high temperatures applied in the process can harm the integrity and longevity of the stored grain (BAKKER-ARKEMA, 1994).

Compromising the nutritional value of the raw material used in formulating the diet to be offered to animals has a significant impact on animal performance, especially in intensive breeding systems that employ many technologies. In pig farming, the early weaning of piglets, with the aim of increasing the productivity of sows, makes the nursery phase decisive, depending on the appropriate combination and use of the ingredients that make up the diet to guarantee the best feed conversion (LOPES, 2000).

Given the above and the scarcity of studies that seek to characterize the quality of silage from rehydrated grains, the present study aimed to evaluate the effect of different corn drying systems on the quality of grains that will later be rehydrated and constitute feed for recently weaned piglets in the form of moist grain silage.

2 MATERIALS AND METHODS

The work was conducted at the Faculty of Agricultural Sciences (FCA) and Faculty of Veterinary Medicine and Animal Science

(FMVZ), both belonging to UNESP, Campus de Botucatu/SP, together with the departments of Rural Engineering and Animal Production, respectively, and was authorized by committee ethics with CEUA Protocol 0275/2018.

The water content of the grains was monitored using the oven method at 105 ±3 °C (BRASIL, 2009) until the first harvest, when the humidity was close to 35% (control). Subsequent harvests were carried out when the water content in the grain reached values close to 22%, 18% and 13%, depending on the treatment.

The treatments consisted of evaluating the wet grain silage (SGU) obtained from naturally ensiled corn (without rehydration - T1 control) and comparing it with the silages obtained artificially through rehydration of the dried grain in three different drying systems: continuous drying at high temperature (T2); in a silo dryer with air at room temperature (T3); and still drying in the plant in the field (T4). After drying, the remoistened grains were ground using a 5 mm sieve, the size recommended for pig feeding (LOPES *et al.*, 2001). They were then hermetically packaged.

During the artificial drying processes, the temperatures of the drying air and the grain mass were monitored using thermoelectric sensors located in the plenum and in the product. In the cross-flow dryer, it took 8 hours to dry the grain, and for drying in the silo, it took 15 days. For drying at the plant, an area of approximately 0.5 hectares was reserved in the production field, where the water content of the grains was monitored until they reached 13% humidity, when mechanized harvesting was then carried out. For the drying treatments (T2, T3 and T4), the water content in the grains was 33%. for its rewetting, according to Costa *et al.* (1999).

2.1 Grain and silage quality analyses

2.1.1 Electrical conductivity of grains

Twenty-five corn grains were counted in four replications per treatment and weighed in a 250 ml tared beaker. Then, 75 ml of deionized water was added to the grains, which were placed in a BOD at a temperature of 20 °C for 24 hours. After the period had elapsed, the solution was gently stirred, and a reading was taken on a bench conductivity meter brand AZ, according to ISTA, as cited and adapted by Paraginski *et al.* (2015).

2.1.2 Chemical analysis and silage pH

At the end of the ensiling period, samples were taken for bromatological analyses of dry matter (DM), crude protein (CP), ether extract (EE) and crude fiber (FB) according to the methodology of Brazil (1978). The pH analysis was carried out in the Grain Processing Laboratory, and the methodology was based on and adapted from the physical-chemical determination manual of the Adolfo Lutz Institute (2008).

2.1.3 Experimental design and statistical analysis of the food quality test

The experimental design was completely randomized, consisting of 4 types of silage (natural moist grain, rehydrated grain after drying at high temperature, rehydrated grain after drying at low temperature, and rehydrated grain after drying in the plant), with four replications, totaling 16 plots**.** The results of the grain electrical conductivity and silage pH were subjected to analysis of variance, and the means were compared using the Tukey test ($p \leq 0.05$) with the GRAPHPAD PRISM 5 statistical program.

2.2 Performance of piglets in the nursery phase

An experiment was carried out in the Teaching, Research and Extension Area (AEPE) of the Faculty of Veterinary Medicine and Animal Science (FMVZ – UNESP - Botucatu/SP) and authorized by the ethics committee with CEUA Protocol 0275/2018. The animals were housed in masonry nursery rooms containing 20 suspended metal pens measuring 1.75 m2 [and] equipped with a feeder, pacifier-type drinking fountain and electric resistance bell for a period of 26 days.

A randomized block design (by weight) was used, with four treatments, five replications and three animals per pen (experimental unit), totaling 60 recently weaned piglets with an average age of 28 days (8.96 kg, ± 1, 40 kg), 30 castrated males and 30 females. The criteria for forming the blocks were weight and sex. The experimental plots were divided into 3 piglets, and the following treatments were randomly distributed to each experimental unit:

T1 - Silage-based feed made from moist corn grains (64.39% DM) that were harvested as soon as they reached physiological maturity, at approximately 33%.

T2 - Silage-based feed made from moist corn grains (65.81% DM) harvested at 22% bu. Immediately thereafter, they were dried at a high temperature of approximately 60 °C to 80 °C under continuous drying.

T3 - Silage-based feed made from moist corn grains (62.17% DM) harvested with a water content of approximately 18%. and subjected to drying in a silo dryer with natural air.

T4 - Silage-based diets made from wet corn grains (61.17% DM) were harvested with approximately 13% bu. after drying in the plant.

The rations were initially formulated based on dry corn. The dry matter contents of the silages were corrected to 88% dry matter (dry corn), and correction factors were used to replace dry corn with the respective silages in the rations (Table 1).

Table 1. Percentage composition and calculated nutritional values of the experimental diets.

Ingredient	Prestart 1	Prestart 2	Home
Corn, Silage	32,816	43,170	58,368
Soybean meal	19,000	24,000	29,000
Sugar	5.00	4,000	3,000
Soy oil	1,500	2,500	3,250
Phosphate	0.300	0.350	0.360
L-Lysine HCl	0.315	0.320	0.440
DL-Methionine	0.160	0.105	0.200
L-Threonine	0.200	0.190	0.227
L-Tryptophan	0.060	0.050	0.045
L-Isoleucine	0.2490	0.095	
L-Valine	0.400	0.220	0.110
Rapid Core 1 ® *	40,000		
Rapid Core 2 ® *		25,000	
Rapid Core 3 ® *			5,000
TOTAL	**100.00**	**100.00**	**100.00**
Calculated nutritional values			
Metabolizable energy (kcal/kg)	3,420	3,394	3,350
Crude Protein (%)	19,390	19,030	18,960
Calcium (%)	0.729	0.824	0.850
Available phosphorus (%)	0.492	0.476	0.432
Digestible Lysine (%)	1,452	1,353	1,248
Digestible Methionine + Cystine (%)	0.873	0.755	0.713
Digestible threonine (%)	0.975	0.901	0.813
Digestible tryptophan (%)	0.276	0.250	0.239
Digestible isoleucine (%)	0.803	0.744	0.692
Digestible valine (%)	1,001	0.292	0.864
Lactose (%)	12,500	8,495	4,500
Sodium (%)	0.293	0.242	0.207

* The description of the composition of the commercial pig nucleus is found in Annex A.
Source: The authors

The following three-phase feeding programme was used: phase 1, pre-initial diet 1 (0-11 days); phase 2, preinitial diet 2 (12-18 days); and phase 3, initial diet (19 to 26 days). All diets were isoenergetic, isoproteic and formulated to meet the minimum nutritional requirements of the animals, according to Rostagno (2017).

To evaluate performance, the animals, the feed provided and the leftovers were weighed at the beginning and end of each phase of the experiment to determine daily weight gain, daily feed consumption and feed conversion. The data were subjected to analysis of variance using the SAS PROC GLM procedure, and the means were compared using the Tukey test with a significance of 5%.

RESULTS AND DISCUSSION

To characterize the food obtained in Table 2, the results of the bromatological analysis carried out on the silage from each treatment are presented, with a minimum ensiling time of 28 days.

Table 2. Average percentages of dry matter (DM), crude protein (CP), ether extract (EE), and crude fiber (FB) in the silages tested.

Treatment	MS [%]	BP [%]	AND IS [%]	FB [%]
T1	64.39	8.89	2.76	1.66
T2	65.81	9.59	3.16	1.77
T3	62.17	8.86	3.1	1.62
T4	61.17	8.86	2.89	1.78

Source: The authors

Comparing the levels of crude protein, ether extract and crude fiber, it can be seen that there were no major variations between treatments and that all silages obtained in the first stage of the present research presented a compatible composition in relation to those obtained from naturally moist or rehydrated grains (OLIVEIRA *et al.*, 2004).

The greater variation between the dry matter contents of the silages can be explained by the artificial process of reconstitution of the grains that were dry, which, no matter how standardized it was, did not allow for uniform water absorption by the material. It is noteworthy that the values achieved were within those recommended by practice, that is, a water content in the grains between 30% and 40%.

Table 3 presents the average values of the electrical conductivity (EC) of the grains without a storage period, the pH of the silages obtained from naturally moist grains (T1) and the reconstitution of dried grains in different drying systems (T2, T3 and T4).

Table 3. Average values of electrical conductivity and pH for sealing naturally moist grains (T1) and reconstitution of dried grains at high temperature (T2), at low temperature (T3) or in the plant (T4).

Treatment	EC of grains (μS.cm $^{-1}$. g $^{-1}$) *	Silage pH*
T1	7.51 to	4.30 bc
T2	17.34b	4.32c
T3	8.40 to	4.15 to
T4	11.25 to	4.23b

(*) means followed by the same letter do not differ from each other according to the Tukey test ($p > 0.05$).
Source: The authors

The average EC values obtained in the treatments ranged from 7.51 μScm $^{-1}$ g $^{-1}$ (T1) to 17.34 μScm $^{-1}$ g $^{-1}$ (T2), indicating relatively low values, which indicates good initial conditions for the grains. The electrical conductivity of grains is another variable that can contribute to estimates of cellular content losses during the ensiling process. Grains with a lower electrical conductivity indicate less degradation in the integrity of cell membranes and their maintained quality. Greater losses of sugars and solutes occur proportionally to the higher electrical conductivity measured in the grains due to damage to cell membranes.

Considering the results of this analysis, it appears that the grains that did not undergo drying (T1) or that underwent drying at low temperatures (T3 and T4) presented the best conservation (lower electrical conductivity values) compared to those that underwent drying at high temperatures (T2). Therefore, drying at high temperature (T2) had a deleterious effect on the integrity of the corn grains.

The maximum allowable drying temperature must depend on the nature of the product and the purpose for which it is intended. The temperature that can damage a seed varies depending on the species and its initial moisture content. For most species, a drying temperature of 32 °C is recommended when the moisture content is greater than 18%.

and 38 °C when it is between 11 and 18%, these values are determined in the seed mass (CARVALHO; NAKAGAWA, 1988).

Although the pH values of all treatments were very close to each other and to the expected range for quality fermentation (between 3.8 and 4.2), there were significant differences between the averages, with the best values being observed in T3 (4.15) and the highest values in T2 and T4 (4.32 and 4.23, respectively) (Table 3). Igarasi *et al.* (2008) obtained similar results, with pH values ranging from 4.50 to 4.68 for treatments using approximately 35% moisture, considering that the pH of reconstituted moist grain silages can be greater than that of conventional grain silages (LOPES *et al.*, 2005).

Consistent with the results obtained in the electrical conductivity analysis, it was observed that drying at high temperature also harmed fermentation during ensiling, and the resulting pH values were among the highest. The greater loss of solutes through the cell membrane of grains dried at high temperature may delay the beginning of sugar fermentation by lactic acid bacteria (LAB), compromising the reduction in the final pH of the silage.

Table 4 shows the performance data of the piglets in the nursery phase during the three experimental periods monitored: from 0 to 11 days, from 0 to 18 days and from 0 to 26 days of age.

Table 4. The average initial weight (Pi), final weight (Pf), daily feed intake (CDR), daily weight gain (GDP), and feed conversion ratio (CA) of the piglets were measured during the experimental period (26 days).

	Treatments[1]					
Variables	**T1**	**T2**	**T3**	**T4**	**CV [2]**	***P value***
Days 0 to 11						
Pi (kg)	9,028	8,888	8,921	9,007	1,945	0.5485
Pf (kg)	11,480 ab	11,910th	11,970th	11,330b	2,526	0.0122
CDR (g)	0.398	0.443	0.430	0.396	7,237	0.0690
GDP (g)	0.224 bc	0.275 ab	0.277th	0.211c	11,244	0.0044
HERE	1,782 ab	1,559 bc	1,558c	1,899 to	6,760	0.0023
Days 0 to 18						
Pf (kg)	16,444	16,923	17,197	16,241	3,654	0.1031
CDR (g)	0.693	0.723	0.706	0.706	5,011	0.6218
GDP (g)	0.412	0.446	0.460	0.402	8,178	0.0703
HERE	1,656 ab	1,623 ab	1.537b	1,768 to	6,367	0.0294
Days 0 to 26						
Pf (kg)	22,238	22,646	22.101	21,543	3,420	0.1988
CDR (g)	0.950	0.982	0.996	0.986	4,104	0.3465
GDP (g)	0.508	0.529	0.507	0.482	5,931	0.1588
HERE	1,880	1,858	1,983	2,056	6,257	0.0797

[1] Means in lines with different letters differ from each other according to Tukey's test (P<0.05).
Source: The authors

As shown in Table 4, in the first period, there was a significant difference between treatments in terms of final weight, daily weight gain and feed conversion. Notably, for these three variables, the rations from treatments T2 and T3 (artificially dried) provided the best performance. Corn that had dried in the field and was attached to the plant (T4) was the least competitive food. The food considered control (T1), which did not undergo drying, presented intermediate performance and was not significantly different from treatments T2, T3 and T4.

With increasing age, at 18 days, the significant difference between treatments remained only for the feed conversion variable, which also pointed to a better performance of the T3 treatment (dried at low temperature), statistically differentiating itself from T4. (dried on the plant). Despite showing intermediate performance, treatments T1 and T2 did not differ significantly from T3 or T4.

The best FCR during the periods from 0 to 11 and 0 to 18 days obtained in this work corroborates the results presented by Lopes *et al.* (2001), Tófoli *et al.* (2006), Tse *et al.* (2006) and Castro *et al.* (2009), in which structural changes that occurred in the endosperm of ensiled grain and the pH of silage feeds were attributed.

During the ensiling process, changes occur in the grain endosperm due to disruption of the protein matrix (LOPES 2000). There are also structural changes in the starch particles, favoring their digestion (LOPES; LEONEL; CEREDA, 2002). A lower pH can facilitate a decrease in the pH of the stomach and, as a consequence, a higher digestion retention rate, greater activation of pepsins, a reduction in coliform proliferation, greater degradation of dietary minerals and better intestinal health (BERTO; LOPES; COSTA, 2001; SARTORI *et al*.).

When accounting for the total period of performance testing, up to 26 days of age, there was no effect (p >0.05) of the rations on final weight, daily consumption, weight gain or feed conversion. . Similar experiments conducted by Castro *et al.* (2009), Tófoli *et al.* (2006) and Tsé *et al.* (2006) highlighted the absence of effects of wet corn grain silage on these variables during the nursery phase.

On the other hand, although there was no statistically significant difference between the diets with wet grain silage for the nursery period as a whole (0 to 26 days), the significant differences detected in the initial phases (up to 18 days) corroborate the findings of Lima *et al.* (1998), who highlighted that the fermentation that occurs in silage produces food with a higher rate of digestibility and energy availability related to low pH, which facilitates the performance of young animals that have a reduced capacity to acidify food in the stomach.

4 CONCLUSIONS

It is concluded that:

- A high-temperature drying system most affected the quality of the dry grain and the fermentation of the silage made immediately after grain processing;
- The animal performance test detected differences between treatments; in favor of artificial drying of grains, only piglets up to 18 days of age were tested;

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