BIA
BOLETIM DE INDÚSTRIA ANIMAL

Farrage and Pastures

REHYDRATED CORN GRAIN SILAGE WITH WET BREWERY RESIDUE AND DIFFERENT INOCULANTS

Evandro Luiz Lopes Lelis,
Instituto Federal de Educação, Ciência e Tecnologia do Sudeste de Minas Gerais – Campus Rio Pomba, Rio Pomba, MG, Brazil.
https://orcid.org/0000-0003-2969-933X
Email correspondente: evandrocanaa@yahoo.com.br

Valdir Botega Tavares,
Instituto Federal de Educação, Ciência e Tecnologia do Sudeste de Minas Gerais – Campus Rio Pomba, Rio Pomba, MG, Brazil.
https://orcid.org/0000-0001-7228-1532

Rafael Monteiro Araújo Teixeira,
Instituto Federal de Educação, Ciência e Tecnologia do Sudeste de Minas Gerais – Campus Rio Pomba, Rio Pomba, MG, Brazil.
https://orcid.org/0000-0002-8443-8020

Bruno Grossi Costa Homem,
Embrapa Agrobiologia, Seropédica, Rio de Janeiro, RJ, Brazil.
https://orcid.org/0000-0001-7787-0133

Cristina Henriques Nogueira,
Instituto Federal de Educação, Ciência e Tecnologia do Sudeste de Minas Gerais – Campus Rio Pomba, Rio Pomba, MG, Brazil.
https://orcid.org/0000-0001-6401-1532

José Maria da Silva,
Universidade Federal de Viçosa, Viçosa, MG, Brazil.
https://orcid.org/0000-0001-8010-8078

Received: 30/05/2023
Approved: 15/05/2024

Abstract

The objective was to evaluate the effects of including different proportions of Wet Brewery Residue (WBR) using inoculants on rehydrated ground corn silage quality. The experiment was conducted in a completely randomized design in a 4 x 3 factorial scheme with four replications. Four combinations of WBR and ground corn were evaluated to achieve 45 (DM45), 50 (DM50), 55 (DM55), and 65% (DM65) of dry matter (DM) in the homogenized material before siling, and three types of inoculation: without inoculant, with *L. plantarum* + *P. acidylactici* (Homo) and with *L. buchneri* (L. B). Ensiling was done in experimental PVC silos (±4.0kg) and stored for 180 days. The variables obtained were analyzed by the analysis of variance and regression procedures (P<0.05) using the R software. The percentage of real DM included in the treatments was 47%, 52%, 56%, and 66%. No impairment of the pH-reducing capacity of corn rehydrated with WBR was observed. Total dry matter losses were within the acceptable limit in silage with 52% DM (DM50), regardless of the type of inoculation. Gas losses were within the permissible limit only in the DM50 treatments with Homo inoculant and in the DM50 treatment without inoculation. Effluent losses were outside the tolerable limit in the treatment with 47% DM (DM45) in the presence of the inoculant LB. There was a significant interaction between the inoculant LB and the silages, with 47% (DM45) and 56% (DM55) DM for the Crude Protein (CP) levels. The ADF and NDF variables reduced linearly as a function of the increase in dry matter of the ensiled material, with a tendency for the lowest values to be found in treatments without inoculation. For all variables, an increase in energy levels (Non-Fibrous Carbohydrates, starch, Total Digestible Nutrients, and Net Energy gain) was observed with the increase in the DM content of the silage. It is concluded that silage with 52% DM (DM50) obtained the best results for fermentative losses. For bromatological and energetic characteristics, silage with 66% DM was the best, except for the CP variable, where 47% DM silage achieved superior results. In general, the addition of additives did not show any improvement in relation to treatments without inoculants.

Keywords

Additive, Energy, Dry matter, Starch.

SILAGEM DE GRÃO DE MILHO REIDRATADO COM RESÍDUO ÚMIDO DE CERVEJARIA E DIFERENTES INOCULANTES

RESUMO

Objetivou-se avaliar os efeitos da inclusão de diferentes proporções de Resíduo Úmido de Cervejaria (RUC) com uso de inoculantes na qualidade da silagem de grão de milho moído reidratado. O experimento foi conduzido em delineamento inteiramente casualizado em esquema fatorial 4 x 3, com quatro repetições. Foram avaliadas quatro combinações de RUC e grão de milho moído para alcançar 45 (MS45), 50 (MS50), 55 (MS55) e 65% (MS65) de matéria seca (MS) no material homogeneizado antes da ensilagem, e três tipos de inoculação: sem inoculante com *L. plantarum* + *P. acidilactici* (Homo) e com *L. buchneri* (LB). A ensilagem foi feita em silos experimentais de PVC (±4,0kg) e estocadas por 180 dias. As variáveis obtidas foram analisadas pelos procedimentos da análise de variância e regressão (P<0,05) utilizando o software R. A porcentagem da MS real ensilada nos tratamentos foram 47%, 52%, 56% e 66%. Não foi observado comprometimento da capacidade de diminuição do pH do milho reidratado com RUC. As perdas de matéria seca total ficaram dentro do limite aceitável na silagem com 52% de MS (MS50), independentemente do tipo de inoculação. As perdas de gases ficaram dentro do limite aceitável apenas nos tratamentos MS50 com inoculante Homo e no tratamento MS50 sem inoculação. As perdas de efluentes ficaram fora do limite tolerável no tratamento com 47% de MS (MS45) na presença do inoculante L.B. Houve interação significativa entre o inoculante L.B e as silagens com 47% (MS45) e 56% (MS55) de MS para os níveis de Proteína Bruta (PB). As variáveis FDA e FDN reduziram linearmente em função do aumento de matéria seca do material ensilado, com tendência de os menores valores serem encontrados nos tratamentos sem inoculação. Para todas as variáveis, foi observado um incremento nos níveis de energia (Carboidratos não Fibrosos, amido, Nutrientes Digestíveis Totais e Energia Líquida de ganho) com o aumento do teor de MS da silagem. Conclui-se que para as perdas fermentativas a silagem com 52% de MS (MS50) foi o que obteve os melhores resultados. Para as características bromatológicas e energéticas a silagem com 66% de MS foi a melhor, exceto para a variável PB que a silagem 47% MS alcançou resultado superior. De forma geral, a adição de aditivos não apresentou melhoria em relação aos tratamentos sem inoculantes.

Palavras-chave

Aditivo, Amido, Energia, Matéria seca.

INTRODUCTION

Ground corn is the main source of energy used in animal feed concentrates (FAUSTINO et al., 2020). Approximately 75% of the energy value of corn grain is derived from starch. Often, this starch is not fully available for animal use, since commercial hybrids in Brazil are preferably of high vitreousness, the protein matrix is dense, with structured protein bodies, which surround the starch granules (OLIVEIRA et al., 2019), having to use some technique to improve its availability (GRANT and FERRARETTO, 2018).

Rehydrated corn grain silage can be an excellent alternative in order to increase the digestibility of starch granules. It consists of harvesting the grain in full maturity stage (85 – 90% dry matter), followed by grinding and then rehydrated, raising its humidity from 30 to 40% and ensiled (CARVALHO et al., 2017). This better use of ensiled grains is attributed to the proteolysis that occurs in silage by the action of bacteria and microbial enzymes in the protein matrix involving starch granules (KUNG JR et al., 2018).

The success in using corn grain silage rehydrated is highly affected by the rehydration process (MOMBACH et al., 2019), because if the incorporation of water to the corn occurs by a non-rigorous mixture, the hydration of the grain will not be perfect, which may result in loss of DM from the silage material (FAUSTINO et al., 2020). An alternative to improve this mixture for small producers is the inclusion of materials with high moisture content, without causing loss of its nutritional value, an example of this is the brewery wet residue (BWR) which has good nutritional value.

BWR has a high protein content (28.1%), higher than corn, with an excellent amino acid profile, with good levels of methionine that associates well with soybean meal because it contains good levels of lysine, enabling a more balanced diet in terms of amino acids (SCHEID and GUERIOS, 2021). In addition, it has neutral detergent fiber (NDF) that reaches 49.3% and is considered good quality (NRC, 2021). However, it presents storage challenges due to high humidity (78.5%). Segundo Bueno et al. (2020) mixing dry with wet ingredients can minimize the risk of effluent production and undesirable fermentation. In this sense, WBR can be used as a moisture source for rehydration of dry ground grain, resulting in moisture suitable for silage. On the other hand, corn would provide an adequate substrate concentration for silage fermentation and improvement in the preservation of nutritional value and storage of WBR.

The use of inoculants for silage, such as the homofermentative bacteria of the type *Lactobacillus plantarum*, *Pediococcus acidilactici* and *Enterococcus faecium* aims for improving the fermentation process, through an efficient acidification in order to provide adequate conservation. The heterofermentatives bacteria such as *Lactobacillus buchneri*, can increase the aerobic stability of the material, preventing the proliferation of pathogenic microorganisms (MORAIS et al., 2017).

The use of alternative foods, such as agro-industrial waste, in the feeding of ruminants is an alternative to reduce production costs, in addition to promoting less environmental pollution. These advantages can be enhanced if there are lower losses in the fermentation process, which in turn has been associated with the presence of inoculants. Therefore, the present study aimed to evaluate the effects of the inclusion of different proportions of WBR, with or without the use of inoculants, on the quality of rehydrated corn grain silage.

MATERIAL AND METHODS

The experiment was conducted at the Department of Zootechnics of the Federal Institute of Education, Science and Technology of Southeastern Minas Gerais – Campus Rio Pomba, Minas Gerais, Brazil. The raw material for silage consisted of wet residue from brewery – WBR (27% DM) purchased in brewery located in the city of Cláudio-MG and commercial grain corn (12% DM), purchased in the local market. The inoculants were purchased through commercial products, based on a source of homofermentative bacteria *Lactobacillus plantarum*$4x10^{10}$ UFC/g) and *Pediococcus acidilactici* ($4x10^{10}$ UFC/g) - Kerasil® (Kera Nutrição Animal) and heterofermentative bacteria *Lactobacillus buchneri* ($5x10^{4}$ UFC/g) - Lalsil® (Lallemand).

The experiment was conducted in a completely randomized design, in a double factorial scheme (4x3), with four replications. The treatments consisted of 4 different amounts of WBR and dry ground corn grain to reach the DM levels of 45% (DM45), 50% (DM50), 55% (DM55) and 65% (DM65) in the homogenized material before silage (Table 1) and 3 types of inoculation: (1) heterofermentative bacteria - *L. buchneri* (LB); (2) homofermentative bacteria - *L. plantarum* and *P. acidilacticii* (homo) and (3) without inoculant.

Table 1. Proportions of corn and wet brewery residue (WBR) used for Factor 1 composition and Factor 2 inoculants.

Treatments	Factor 1: corn:WBR ratio in silage		Target dry matter (%)	Factor 2: Inoculant
	Corn (%)	WBR (%)		
T1	29.5	70.5	45	LB
T2	38.0	62.0	50	LB
T3	46.0	54.0	55	LB
T4	62.0	38.0	65	LB
T5	29.5	70.5	45	Homo
T6	38.0	62.0	50	Homo
T7	46.0	54.0	55	Homo
T8	62.0	38.0	65	Homo
T9	29.5	70.5	45	Without inoculation
T10	38.0	62.0	50	Without inoculation
T11	46.0	54.0	55	Without inoculation
T12	62.0	38.0	65	Without inoculation

The corn, in commercial grain, was crushed in a hammer mill, equipped with a 4 mm diameter sieve and rehydrated with different levels of WBR. The corn:WBR proportions were calculated using Pearson's square aiming at the final DM of each treatment. The ingredients were added to a container and homogenized manually. In this step, inoculants diluted in distilled water were added, following the manufacturer's recommendation and the treatment without inoculant received the same proportion of distilled water. Then the mixture was placed in silos of PVC pipes, with a diameter of 10 cm and a height of 50 cm, and compacted with wooden pendulums. At the base of each silo, 0.5 kg of fine dry sand was placed inside a NWF cloth (non-woven fabric) separated from the silage material. Each set (tube + lid + sand + cloth) were weighed and sealed with PVC lids coupled to Bunsen valves to allow fermentation gases to escape and prevent air from entering. The silos were stored for 180 days in a covered area and at room temperature. At the time of silage, a sample of each treatment was collected to determine the initial bromatological chemical composition (Table 2).

The addition of WBR to corn in the proportions defined in the present study, exceeded in 1.91, 1.85, 0.81 and 0.82% the estimated value of dry matter (DM) of the treatments of 45%, 50%, 55% and 65%, respectively. Thus, the observed DM values were 46.91%, 51.85%, 55.81% and 65.82%. These values were considered for analysis and interpretation of the results since it is the composition in real ensiled DM.

After 180 days of silage, the silos were weighed to determine the losses that occurred during the fermentation process. Effluent and gas losses were determined according to the methodology described by Jobim et al. (2007) and for the

Table 2. Average contents of bromatological characteristics and energy values of ground corn grain with different levels of WBR, before silage.

Analysis	Dry matter content of the silage mixture %			
	DM45	DM50	DM55	DM65
Dry Matter	46.91	51.85	55.81	65.82
Crude Protein	19.12	17.57	16.18	14.61
NDIP	2.52	2.34	2.06	1.85
ADF	10.59	9.74	7.42	6.01
NDF	23.36	22.52	18.21	15.20
Ash	2.20	2.31	2.83	2.42
Starch	43.78	45.83	51.89	57.53
NFC	52.43	54.44	59.89	65.34
TDN	80.13	80.46	81.70	83.00
NEG	1.81	1.80	1.81	1.81

Legend: NDIP - Neutral detergent insoluble protein; ADF - Acid detergent fiber; NDF – Neutral detergent fiber; NFC – non-fiber carbohydrates; TDN – Total Digestible nutrients; NEG - Net Energy gain.

determination of total dry matter losses (TDML) the methodology described by Silva and Queiroz (2006) was used. The losses were calculated using the following equations:

$$Pefluentes = \frac{(PCabert - PCens)x100}{MVAens}$$

$$Pgases = \frac{\{[(PTCens - PCens)xMSens] - [(PTCabert - PCens)xMSabert]\}x100}{(PTCens - PCens)xMSens}$$

$$PMST = \frac{\{[(PTCens - PCens)xMSens] - [(PTCabert - Cabert)xMSabert]\}x100}{(PTCens - PCens)xMSens}$$

Where:

Peffluent = loss per effluent (% of ensiled natural matter);

Pgases = gas loss calculated as a function of ensiled dry matter (%);

TDML = total dry matter loss as a function of ensiled dry matter (%);

GMSens = green mass of sample in silage.

PTCens = total weight of the set in silage (sample + silo + lid + NWF with dry sand);

TWSopen = total weight of the set at the opening (sample + silo + lid + NWF with wet sand);

WSs = weight of the set in silage (silo + lid + NWF with dry sand);

WSopen = set weight at opening (silo + lid + NWF with wet sand);

DMs = % of sample dry matter in silage;

DMopen = % dry matter of the sample at the opening.

After determining the fermentative losses, the upper material of each silo was discarded and the central material of the silo was homogenized, and a sample (9 g) was taken for pH analysis. The sample was placed in 60 ml of distilled water for 30 minutes, followed by direct reading of the hydrogenionic potential using a benchtop pH meter. The rest of the material was used to collect samples that were sent to the laboratory (3RLAB, 2021).

The NIRS type analyzes (SILVERSTEIN, 2019) were performed in a 3Rlab laboratory to determine the contents of dry matter (DM), crude protein (CP), neutral detergent insoluble protein (NDIP), neutral detergent fiber (NDF), acidic detergent fiber (ADF), starch, non-fiber carbohydrates (NFC), total digestible nutrients (TDN) and net gain energy (NEG) for dairy cattle, following the NRC 2001.

The variables obtained after opening the silos were analyzed by analysis of variance and regression ($p<0.05$). Shapiro-Wilk ($\alpha= 0.05$) and Bartlett ($\alpha=0.05$) tests were performed for normality of residuals and homogeneity of variances, respectively. ANOVA was then performed using the significance of the F-test at 5% probability. When the interaction was significant ($p<0.05$), the unfolding of the interaction was performed, analyzing the inoculating factor through the Tukey test ($p < 0.05$) and the dry matter levels factor by regression analysis. The choice of the regression model was based on the significance of the coefficients (linear and/or quadratic), test for the lack of adjustment ($p \geq 0.05$) and the coefficient of determination (r^2). All analyses were performed using the ExpDes.pt package (FERREIRA et al., 2014) from R software (R CORETEAM, 2022).

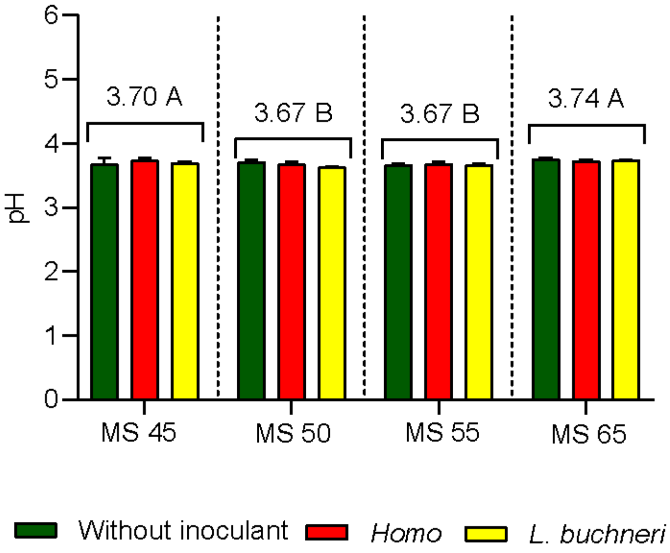
RESULTS

Fermentative Losses and pH

For pH (Figure 1) there was no significant interaction between DM levels and types of inoculants. The pH was influenced (P=0.000112) by the different DM levels of the silage. There was no difference in silage pH between the inoculants.

The interaction effect ($P<0.05$) among the percentages of DM and the inoculants. The highest loss of total dry matter was observed for DM45, regardless of the use of inoculant and the lowest losses were observed for DM50, without the use of inoculant (Table 3).

Figure 1. pH values of silages with different DM and inoculants.



Without inoculant - without the addition of inoculant; Homo - inoculant homofermentative bacteria *Lactobacillus plantarum* and *Pediococcus acidilactici*; *L. Buchneri* (LB) - inoculant *L. buchneri*. Means followed by the same capital letter, do not differ from each other by the Tukey test 5% probability.

In the evaluation of gas losses (Table 3), the highest losses were also observed for the treatment of DM45, no difference between types of inoculation and the lowest gas losses were observed for the treatment DM50, inoculated with LB and without inoculation. As for the losses by effluents, the greatest losses were also in the treatment with DM45 and with the use of the inoculant LB.

Table 3. Values of total dry matter losses, gases and effluents of corn grain silages rehydrated with WBR for different dry matter contents for silage, with the presence or not of inoculants.

Inoculant	**Dry matter (%)**				**CV (%)**
	DM45	**DM50**	**DM55**	**DM65**	
Total dry matter losses %					
[3]LB	21.57 Aa	5.11 Da	8.52 Ba	6.90 Ca	4.65
[2]Homo	21..99 Aa	5.91 Ca	7.70 Ba	7.59 Ba	
[1]Without inoculant	19.59 Aa	3.95 Cb	7.64 Ba	6.93 Ba	
Gas loss %					
LB	17.23 Aa	1.90 Cb	7.17 Ba	5.40 Ba	8.42
Homo	17.32 Aa	3.28 Ca	6.18 Ba	5.81 Ba	
Without inoculant	14.66 Aa	1.71 Db	7.39 Ba	5.37 Ca	
Effluent loss %					
LB	7.25 Aa	2.05 Ba	1.46 Ba	1.57 Ba	15.90
Homo	6.22 Ab	2.70 Ba	1.60 Ca	1.88 BCa	
Without inoculant	5.57 Ab	2.08 Ba	1.61 Ba	1.59 Ba	

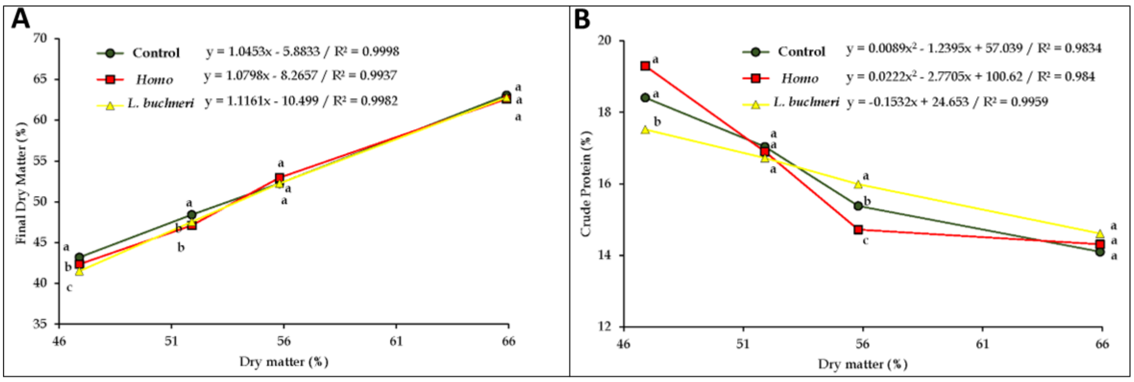
[1]Without inoculant - without the addition of inoculant; [2]Homo-inoculant homofermentative bacteria *Lactobacillus plantarum* and *Pediococcus acidilactici*; [3]LB-inoculant *L. buchneri*. Means followed by the same letter, uppercase in the row and Lowercase in the column do not differ from each other by the Tukey Test at 5% probability.

Bromatological Features

Significant interaction was observed between the percentage of DM and inoculants ($P<0.05$) (Figure 2A). In the DM45 treatment, inoculation with LB had the highest dry matter losses in relation to Homo and without inoculation. In the DM50 treatment, silage without inoculation showed lower losses. In the DM55 and DM65 treatments there were no significant differences for the inoculating factor. DM levels were influenced by the treatments comparing the material before silage with the material after silage. There was a reduction in the percentage of silage DM that were higher in silage DM45: 4.71%, DM50: 4.17% in relation to DM55: 3.33% and DM65: 3.0%.

For the characteristic CP there was significant interaction between the percentage of DM and the inoculants. CP decreased with the increase of DM content of the silage. This effect was represented by the quadratic decreasing model for the Homo inoculant. The minimum point of the model was estimated at the 63.04% DM level. At this DM level, CP reached a minimum of 14.10% (Figure 2B). This same model was adjusted for silage without inoculant in which the minimum point of the model is observed when reaching the level corresponding to 69.4% DM, which is outside the range of the present study. The increase in DM linearly reduced the CP content of the silage in the presence of the LB inoculant, for each unit increased in the DM content, it was estimated a reduction of 0.15 units in the CP content of the silage.

Figure 2. Mean values of dry matter (A) and crude protein (B) of corn grain silages rehydrated with WBR, with different DM levels, without and with the presence of inoculants.



Without inoculant - without the addition of inoculant; Homo-inoculant homofermentative bacteria *Lactobacillus plantarum* and *Pediococcus acidilactici*; *L. Buchneri* (LB) - inoculant *L. buchneri*. Means followed by the same lowercase letter do not differ from each other by the Tukey Test at 5% probability.

Differences were observed between CP levels depending on the form of inoculation in DM45 and DM55 treatments. In DM45, the LB (17.52% of CP) presented lower value statistically than the other treatments (without inoculant 18.94% of CP and Homo 19.30% of CP). In DM55, LB had the highest CP content (15.99%), followed by silage without inoculant (15.38%) and Homo inoculant with the lowest amount of CP (14.72%).

The ADF and NDF variables decreased linearly as a function of the increase in DM (quantitative factor) of the silage material (Figure 3A) and (Figure 3B). In the ADF, in relation to inoculants, silage without inoculant presented lower ADF values, however, in DM45 and DM55 treatments there was no significant difference in relation to Homo. In NDF, for the inoculant type factor, in DM45, DM50 and DM65, silage without inoculant had lower values statistically in relation to those with inoculants. In DM55, the Homo inoculant showed lower value than the other treatments.

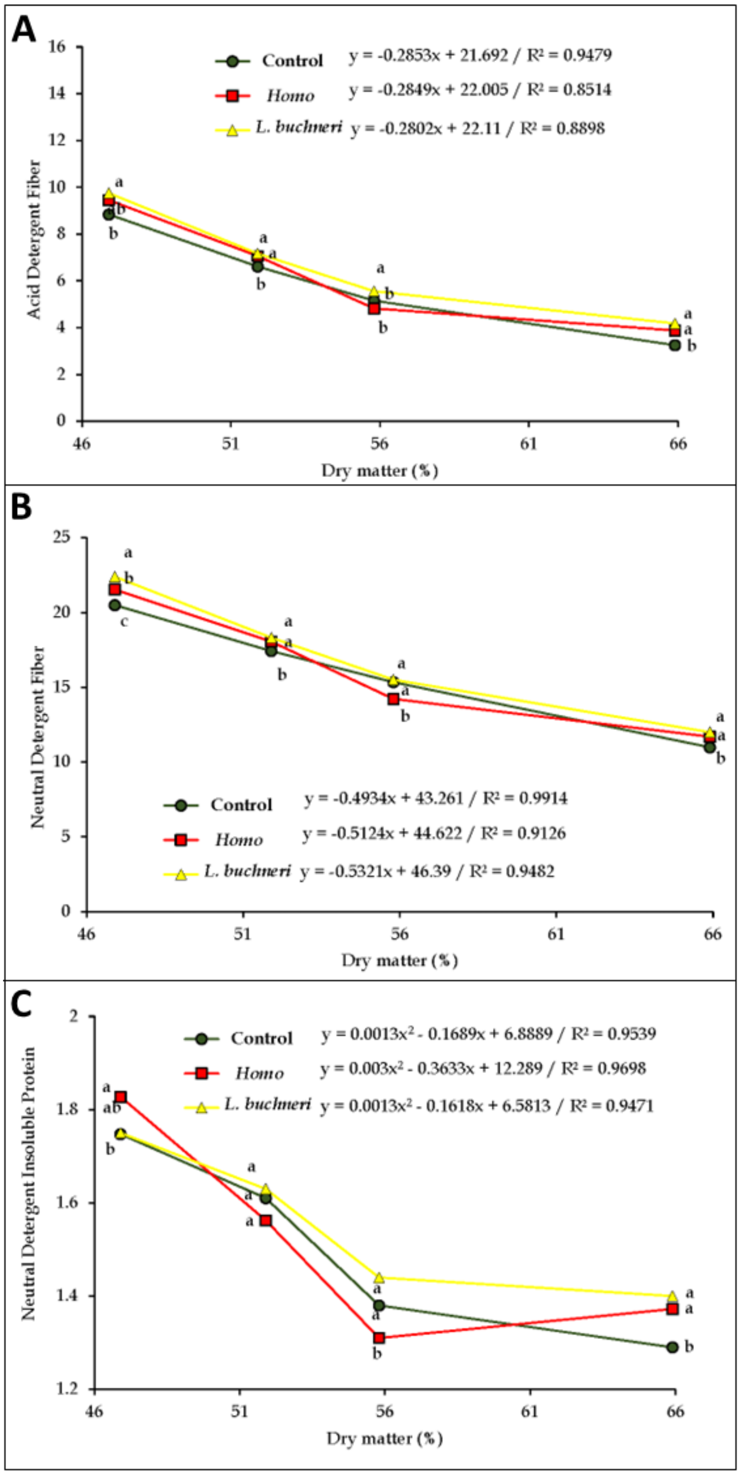
Regarding the NDIP (Figure 3C), a significant interaction was observed between the factors percentage of DM and types of inoculants. The NDIP value showed quadratic responses in all types of inoculants. The minimum values of the model for no inoculant, Homo and LB were obtained when reaching 64.96, 60.55 and 62.23% DM, respectively. At these DM levels, it was estimated the levels of 1.40, 1.29 and 1.55% in NDIP for silage without inoculant, Homo and LB, respectively.

Energy Value

For all variables, an increase in energy levels was observed with increasing DM content of silage (Figure 4). This increase was represented by the linear model for the variables NFC, starch, TDN, NEG in the factors without inoculant and with the Homo inoculant and by the quadratic model for the variable NEG when the LB inoculant was used. The maximum NEG value was observed when it hit DM levels corresponding to 68.67%, which is outside the range investigated.

Regarding starch (Figure 4A), there was a decrease in concentrations in relation to the material before silage compared to silage, where in DM45 was a sharp reduction reaching 11.8 percentage points in Homo treatment. The smallest loss, corresponding to 1.3 percentage points of the mass silaged, was observed in the silage without inoculant of treatment DM65. In relation to the inoculants within each dry matter level, the Homo treatment presented significantly lower values in relation to

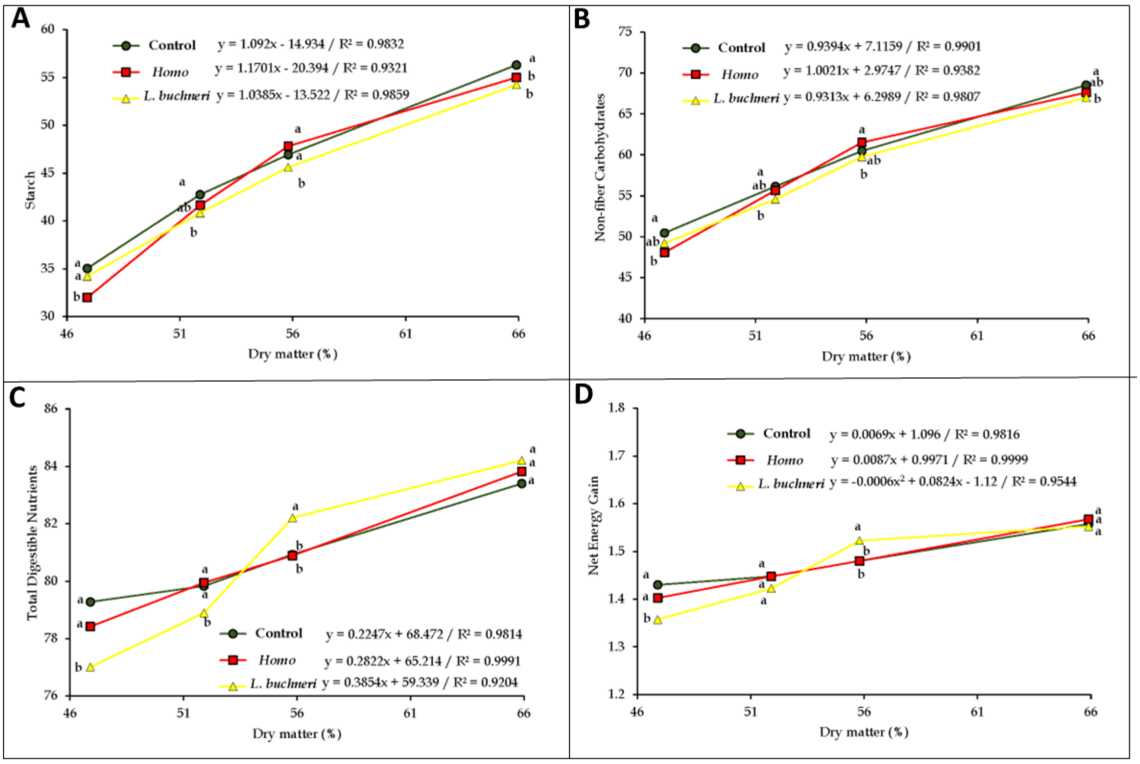
Figure 3. Values of ADF (A), NDF (B), NDIP(C) of corn grain silages rehydrated with WBR, with different dry matter contents, without and with the presence of inoculants.



Without inoculant - without the addition of inoculant; Homo-inoculant homofermentative bacteria *Lactobacillus plantarum* and *Pediococcus acidilactici*; *L. Buchneri* (LB) - inoculant *L. buchneri*. Means followed by the same lowercase letter do not differ from each other by the Tukey Test at 5% probability.

the others, for DM45. In the dry matter levels DM50 and MD55, LB presented lower values in relation to without inoculant, but did not differ statistically from Homo inoculant in DM50. However, in DM65 the absence of inoculants presented a higher

Figure 4. Starch values % DM (A), NFC (B), TDN (C) and NEG (D) of corn grain silages rehydrated with WBR, with different dry matter contents, without and with the presence of inoculants.



Without inoculant - without the addition of inoculant; Homo - inoculant homofermentative bacteria *Lactobacillus plantarum* and *Pediococcus acidilactici*; *L. Buchneri* (LB) - inoculant *L. buchneri*. Means followed by the same lowercase letter do not differ from each other by the Tukey Test at 5% probability.

amount of starch in relation to treatments with inoculation.

For the NFC in relation to the presence of inoculants, in DM45 Homo presented lower significant values in relation to without inoculants, but did not differ statistically from LB. In DM50 and DM65 treatments, without inoculant was higher than LB, but it did not differ from Homo inoculant, whereas in DM55 Homo was higher than LB. In relation to non-silaged material, DM45 lost NFC. For DM65, all treatments increased the percentage of NFC.

For the TDN (figure 4C), in relation to the inoculants, LB was significantly lower in relation to the others in the DM45 and DM50 treatments. In DM55, LB was higher. In DM65 there was no significant difference between treatments. In relation to NEG (figure 4D), the presence of LB inoculant in DM45 presented a significantly lower value compared to the others. In DM55, LB was higher than Homo and without inoculant and in DM50 and DM65 there was no difference between treatments.

DISCUSSION

There was no impairment of the ability to decrease the pH of the ground corn grain rehydrated with WBR for the amounts of dry matter in the material to be siled, obtained in the present study. The pH values of the treatments are close to those considered ideal from 3.8 to 4.2 (McDONALD et al., 1991). The pH values were similar to those reported by Ferraretto et al. (2018) comparing WBR and corn mixtures to achieve 60, 65, 70% DM, with pH values below 4 with 28 days of fermentation, demonstrating the possibility of using the material as a pH reduction

According to McDonald et al. (1991), the limit value considered appropriate for total effluent losses in silages ranges from 5 to 7%. In the present study, only the DM45 with the LB inoculant was not within this limit, with a value of 7.24% of losses. The gas losses presented values considered acceptable of 1 to 2% of the total energy losses (MOMBACH et al., 2019) only in DM50 silage, within the levels without inoculants (1.98%) and LB (1.90%). The remainder was above ideal, especially with DM45, with losses of 17.23, 17.32 and 14.66%, for LB, Homo and without inoculant, respectively. At levels close to 45% DM, gas losses are enhanced by the fermentation of CO2-producing microorganisms. This is due to the activity of bacteria of the genus *Clostridium,* enterobacter and yeasts that promote decarboxylation and/or oxidation during the fermentative process (McDONALD et al., 1991).

For the pmst values, silage MS50 was the one that was closest to the 5% of losses accepted for silage materials, according to Mombach et al. (2019). The greatest losses occurred in silage DM45 being well above the ideal, without changes with the presence or absence of inoculants. This increase in losses is justified by gas losses, since these are accounted for in the TDML.

Oliveira et al. (2019) studying corn grain silage rehydrated at 33% humidity, siled for 45 days and inoculated with *L. plantarum* and *Propionibacterium acidipropionici,* verified values of TDMLof 12.5, 17.5 and 15.4% in DM, for the control treatments, presence of the enzyme glucoamylase and in the presence of the enzyme amylase, respectively. The authors associated these losses with the intensification of microbial activity in silages with highly fermentable carbohydrates.

DM levels were influenced by the treatments comparing the material before silage with the material after silage. There were losses of 4.71% for DM45 silage, 4.17% for DM50, 3.33% for DM55 treatment and 3.01% for DM65 silage.

The present study showed a negative correlation between the reduction of dry matter and the increase in losses. The reduction of DM occurs, since in the process of acidification of the medium there is the consumption of DM by lactic acid-producing bacteria, until the silage material becomes stable. There is a tendency that moisture contents above 35% at the time of silage favor DM losses (PEREIRA et al., 2017). Ferraretto et al. (2018) comparing mixtures of WBR and rehydrated corn to achieve dry matter of 60, 65, 70%, observed that DM had a slight decrease (1 to 2 percentage units) observed for all treatments up to 28 days. In another study, Carvalho et al. (2017) found that the total reduction in DM concentration was 3.2 percentage points of corn grain silage rehydrated at 30% moisture at 180 days.

The fibrous fraction, represented by NDF and ADF, of corn silages rehydrated with WBR suffered a dilution effect after the silage period. The production of organic acids from soluble components has a dilution effect proportional to the fibrous fraction of the silage. This result possibly comes from the occurrence of hemicellulose hydrolysis (WEIMER et al., 2022).

In a meta-analysis with approximately 5,900 samples of corn silage with wet grains, Ferraretto et al. (2014) found mean values of 7.1% for NDF and 2.6% for ADF, lower results than those obtained in the present study. The values closest to these were DM65 silage without the presence of inoculants, 10.9% for NDF and 3.24% for ADF. It was a trend of this study, silages without inoculants presented lower values of NDF and ADF.

The NDIP content decreased from the green mass to be siled to the silage in all treatments, due to the fermentative process (SOUZA et al., 2022). It should be noted that the lower the value of such, the more available the protein content will be for the animal. Being the lowest value found in silage DM65 with LB.

The treatments that received the highest amount of WBR had higher concentrations of CP, which resulted in an increase in the nutritional value of corn grain silage, proportional to the level of added WBR. This resulted in a silage with energy and protein contents approaching the commercial concentrates for ruminants.

CP losses were very small, with the highest loss of 1.6% observed in silage DM45 with the presence of LB inoculant. During silage fermentation, nitrogen loss is typically less significant than other soluble fractions, with minor effects on total CP content. The silage that had the highest loss of CP was precisely the one that had the highest losses of effluents, being outside the measure considered ideal of 5 to 7% DM. This may have occurred due to the degradation of nitrogen compounds through undesirable microbial activity and have led to increases in ammonia content, which is lost via effluents (BUENO et al., 2020). On the other hand, Silva et al. (2019) evaluated silage of corn grains rehydrated at 65% DM with water and with inoculation, and found no significant difference between the treatment with L. *Buchneri* and without inoculant

For the starch concentration of the silage, losses were observed in relation to the non-silage material. Arcari et al. (2016) also observed a reduction in the starch content of rehydrated corn grain silage after 330 days of silage. These same authors justify this loss due to the starch content not being degraded by microorganisms that produce lactate during the silage process.

However, it can be degraded by other bacteria that do not produce lactate, depending on the fermentative activity of the silo. This may explain the great difference between starch losses, being a much more significant loss in silages with higher humidity, reaching a greater loss in DM45 with the presence of the Homo inoculant in the value 11.8 %. The reduction observed by Arcari et al. (2016) reached 2.4% during the total silage period, and at 180 days of silage achieved a loss of 1.15 percentage points, close to 1.21% of treatment DM65 of silage without inoculant.

TDN and NEG maintained the trend of higher results in DM65. Since in this DM content there is a higher concentration of corn, which is rich in energy, compared to the other silages.

CONCLUSIONS

The inclusion of 62% of WBR in the rehydrated corn grain silage, with 50% of dry matter, resulted in the lowest losses of gases, effluents and total dry matter. However, silage with 65% dry matter, obtained with the inclusion of 38% WBR, provided better bromatological and energetic characteristics, except for the crude protein variable where treatments with DM45, corresponding to the addition of 70.5% WBR, achieved superior results. In general, it was not possible to identify improvements with the addition of inoculants in silage quality.

ACKNOWLEDGEMENTS

The Company of Technical Assistance and Rural Extension of the state of Minas Gerais (Emater-MG), Laboratory 3 Rlab Agricultural Analysis Laboratory, Av. Fábio Modesto, 158-Vila Joaquim de Sales, Lavras-MG, 37207-748 and to the Southeast Federal Institute of Minas Gerais for support in translating the article.

REFERENCES

ARCARI, M.A.; MARTINS, C.M.M.R.; TOMAZI, T.; GONÇALVES, J.L.; SANTOS, M. V. Effect of substituting dry corn with rehydrated ensiled corn on dairy cow milk yield and nutrient digestibility. **Animal Feed Science and Technology**, v. 221, p. 167-173, 2016. https://doi.org/10.1016/j.anifeedsci.2016.08.005

BUENO, A.V.I.; LAZZARI, G.; JOBIN, C.C.; DANIEL, J.L.P. **Review Ensiling Total Mixed Ration for Ruminants**: A Review. Maringá, PR: State University of Maringá, 2020.

CARVALHO, B.F.; ÁVILA, C.L.S.; BERNARDES, T.F.; PEREIRA, M.N.; SANTOS, C.; SCHWAN, R.F.; Fermentation profile and identification of lactic acid bacteria and yeasts of rehydrated corn kernel silage. **Journal of Applied Microbiology**, v.122, n.3, p.589-600. https://doi.org/10.1111/jam.13371

FAUSTINO, F.T.; SILVA, D.C.N.; LEITE, F.R.; FLORENTINO, A.L.; REZENDE, V.A. Utilização de grão de milho reidratado e casca de café na alimentação animal. **Revista Científica Rural**, Bagé-RS, v.22, n.1, 2020. https://doi.org/10.30945/rcr-v22i1.371

FERRARETTO, L.F.; SILVA FILHO, W.I.; FERNANDES, T.; KIM, D.H.; SULTANA, H. Effect of ensiling time on fermentation profile and ruminal in vitro starch digestibility in rehydrated corn with or without varied concentrations of wet brewers grains. **Journal of Dairy Science**, v. 101, n. 5, p. 4643-4649, 2018. https://doi.org/10.3168/jds.2017-14329

FERRARETTO, L.F.; TAYSOM, K.; TAYSOM, D.M.; SHAVER, R.D.; HOFFMAN, P.C. Relationships between dry matter content, ensiling, ammonia-nitrogen, and ruminal in vitro starch digestibility in high-moisture corn samples. **Journal of Dairy Science**, v.97, n.5, p.3221-3227, 2014. https://doi.org/10.3168/jds.2013-7680

FERREIRA, E.; CAVALCANTI, P.; NOGUEIRA, D. ExpDes: An R Package for ANOVA and Experimental Designs, **Applied Mathematics**, v. 5, p.2952-2958, 2014. https://doi.org/10.4236/am.2014.519280

GRANT, R. J.; FERRARETTO, L. F. Silage review: Silage feeding management: Silage characteristics and dairy cow feeding behavior. **Journal of Dairy Science**, v. 101, n. 5, p. 4111-4121, 2018. https://doi.org/10.3168/jds.2017-13729

JOBIM, C.C.; NUSSIO, L.G.; REIS, R.A.; Schmidt, P. Avanços metodológicos na avaliação da qualidade da forragem conservada. **Revista Brasileira de Zootecnia**, v.36, p. 101-119, 2007. https://doi.org/10.1590/S1516-35982007001000013

KUNG JR, L.; SHAVER, R. D.; GRANT, R. J.; SCHMIDT, R. J. Silage review:

Interpretation of chemical, microbial, and organoleptic components of silages. **Journal of dairy Science**, v.101, n.5, p.4020-4033, 2018. https://doi.org/10.3168/jds.2017-13909

LABORATÓRIO 3RLAB. **Protocolo de envio de amostras**. Available at: www.3rlab.com.br/analises-de-nirs/. Access on 03/04/2021.

McDONALD, P.; HENDERSON, A.R.; HERON, S.J.E. **The biochemistry of silage**. 2ed. Marlow: Chalcombe Publications, 1991, 340p.

MOMBACH, M.A.; PEREIRA, D.H.; PINA, D.S.; BOLSON, D.C.; PEDREIRA, B.C. Silage of rehydrated corn grain. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.71, n. 3, p. 959-966, 2019. https://doi.org/10.1590/1678-4162-9676

MORAIS, G.; DANIEL, J.L.P.; KLEINSHMITT, C.; CARVALHO P. A.; FERNANDES, J.; NUSSIO, L. G. Additives for Grain Silages: A Review. **Slovak Journal of Animal Science**, v.50, p.42-54, 2017.

NATIONAL RESEARCH COUNCIL - NRC. **Nutrient Requirements of Dairy Cattle**. Eighth Revised edition. Washington, D.C., 2021. 365p.

SOUZA, A. M. D.; NEUMANN, M.; RAMPIM, L.; ALMEIDA, E. R. D.; MATCHULA, A. F.; CRISTO, F. B.; FARIA, M. V. Effect of storage time on the chemical composition of whole and grainless corn plant silage harvested at different maturity stages. **Revista Brasileira de Zootecnia**, v. 51, 2022. https://doi.org/10.37496/rbz5120200180

OLIVEIRA, E.R.; TAKIYA, C.S.; DEL VALLE, T.A.; RENNÓ, F.P.; GOES, R.H.T.; LEITE, R.S.; OLIVEIRA, K.M.P; BATISTA, J.; ARAKI, H. M. C.; DAMIANI, J.; SILVA, M. S.; GANDRA, E.R.S. ; PEREIRA, T. L.; GANDRA, J.R. Effects of exogenous amylolytic enzymes on fermentation, nutritive value, and in vivo digestibility of rehydrated corn silage. **Animal Feed Science and Technology**, v. 251, p.86-95, 2019. https://doi.org/10.1016/j.anifeedsci.2019.03.001

PEREIRA, K. A.; AMARA, A. G.; OLIVEIRA, A. R.; ARCANJO, A. H. M.; CAMPOS, J. C. D. Aspectos Nutricionais e Confecção de Silagem de Grão Úmido de Milho para a Alimentação de Bovinos: revisão de literatura. **Revista Eletrônica Nutritime**, v.14, n.1, p.4944-4953, 2017.

R CORE TEAM. R: A language and environment for statistical computing. **R Foundation for Statistical Computing**, Vienna, Austria, 2022. Available at: https://www.r-project.org/. Access on 09/20/2022.

SCHEID, P. R.; GUERIOS, A. M. E. Suplementação proteica de bovinos leiteiros com resíduo úmido de cervejaria (RUC). **Arquivos Brasileiros de Medicina Veterinária FAG**, v. 4, n. 1, 2021.

SILVA, N. C.; NASCIMENTO, C.F.; CAMPOS, V. M. A.; ALVES, M. A. P.; RESENDE; F. D.; DANIEL, J. L. P.; SIQUEIRA, G. R. Influence of storage length and inoculation with Lactobacillus buchneri on the fermentation, aerobic stability, and ruminal degradability of high-moisture corn and rehydrated corn grain silage. **Animal Feed Science and Technology**, v. 251, p. 124-133. 2019. https://doi.org/10.1016/j.anifeedsci.2019.03.003

SILVA, D.J.; QUEIROZ, A.C. **Análise de alimentos**: métodos químicos e biológicos. 3. ed. Viçosa: UFV, 2006. 235p.

SILVERSTEIN, R.M.; WEBSTER, F.X.; KIEMLE, D.; BRYCE, D. **Identificação Espectrométrica de Compostos Orgânicos**. 8.ed. Rio de Janeiro: LTC, 2019. 468p.

WEIMER, P. J. Degradation of cellulose and hemicellulose by ruminal microorganisms. **Microorganisms**, v. 10, n. 12, p. 2345, 2022. https://doi.org/10.3390/microorganisms10122345