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Fermentation profile and nutritional value of millet grain silages rehydrated with whey and/or molasses

Perfil fermentativo e valor nutricional de silagens de grãos de milheto reidratadas com soro de leite e/ou melaço

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Highlights

Whey can be used to rehydrate grains.
Rehydration is a technique that improves grain digestibility.
Reuse of acid whey prevents its disposal into the environment.

Abstract

This study aimed to evaluate the fermentation profile and nutritional value of millet grain silages rehydrated with whey and/or molasses. The experiment was conducted in a completely randomized design with four treatments and six replications, with a control treatment (water rehydration), whey rehydration, water rehydration plus molasses (2.5%), and whey plus molasses (2.5%). Lower values of dry matter content (DM = 66.37; 1.55%) were found for the control silage, but within the recommended range. The contents of crude protein, neutral detergent fiber, acid detergent fiber, lignin and hemicellulose were not influenced by the use of additives. There was no difference ($p>0.05$) for aerobic stability and ammonia-N (6.04%) between treatments. For pH, lower values were observed for silages with molasses. There was a higher concentration ($p < 0.05$) of lactic acid in silages with whey, and a higher concentration of butyric acid in silages added exclusively with molasses. The use of whey improved dry matter recovery compared to control silages.

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Higher dry matter degradability was observed with 8% rate of passage in silages added with molasses and/or whey in relation to the control.

Key words: Organic acids. Additive. Ruminal kinetics. Aerobic stability.

Resumo

Objetivou-se avaliar o perfil fermentativo e o valor nutricional de silagens de grãos de milheto reidratados com soro de leite e/ou melaço. O experimento foi conduzido em delineamento inteiramente casualizado com quatro tratamentos e seis repetições, sendo tratamento controle (reidratação com água), reidratação com soro de leite, reidratação com água mais melaço (2.5%), e soro de leite mais melaço (2.5%). Observou-se menor teor de matéria seca (MS = 66.37; 1.55%) na silagem controle em relação aos demais tratamentos, contudo este se encontra dentro do limite desejável. Os teores de proteína bruta, fibra em detergente neutro, fibra em detergente ácido, lignina e hemicelulose não foram influenciados pelo uso dos aditivos. Não houve diferença (p >0.05) para estabilidade aeróbica e N-amoniacal (6.04% NT) entre os tratamentos. Para valores de pH observou-se menores valores para as silagens com melaço em relação as demais. Houve maior concentração (p <0.05) de ácido lático nas silagens com soro de leite e maior concentração de ácido butírico nas silagens aditivadas exclusivamente com melaço. A utilização do soro de leite melhorou a recuperação da matéria seca em relação às silagens controle. Observou-se maior degradabilidade da matéria seca com 8% de taxa de passagem nas silagens aditivadas com melaço e/ou soro em relação ao controle.

Palavras-chave: Ácidos orgânicos. Aditivos. Cinética ruminal. Estabilidade aeróbica.

Introduction

The use of grains in animal feed has been consolidated in recent decades, and corn grain (Zea mays) is the main energy source in intensive farming systems (Cruz et al., 2021). As it is an expensive ingredient, the search for substitutes for corn that meet the energy requirements of animals and improve the cost/benefit of farming systems is constant. Among the possible substitutes for corn grain, millet (Pennisetum glaucum L.) is promising because it has intrinsic characteristics that favor its adaptation to different types of climates and soils, and can be grown even in regions with low rainfall and high temperatures.

A disadvantage of using grain in animal feed is the difficulty in storage, so to minimize losses due to attacks by rodents, insects, fungi, and mycotoxins (Cruz et al., 2021). Rehydrated grain silage has been used to reduce possible losses during the grain storage period, and it is already used for corn and sorghum grains (Rezende et al., 2014, 2016; M. R. H. Silva et al., 2018; Mombach et al., 2019). This technology has the advantages of enabling the strategic purchase of these cereals at harvest time, when the price is more accessible. It also allows producers, with limited area for planting grains, to have access to an ingredient of high nutritional value for the preparation of diets. In addition, storing grains as silage eliminates the cost of third-party sheds or silos and eliminates losses from pest attacks (Cruz et al., 2021).

For grain silage making, they go through a rehydration process aiming to reach a moisture content of 30-35%, followed by an anaerobic storage process (Rezende et al., 2014). Although the fermentation of soluble sugars and the production of organic acids, such as lactic acid, by bacteria present in the medium, naturally occur in the silage process, the use of additives can improve the fermentation process and reduce losses in the silage making process (Mombach et al., 2019).

The major by-product from milk processing, whey is the liquid obtained in the process of making cheese and dairy products. Because it is produced in large quantities, whey is usually improperly discarded, contributing to increased damage to the environment. A viable destination for this product is its reuse in the hydration of grains for silage production (Rezende et al., 2014; Cruz et al., 2021). Its potential use as an additive in the silage process is related to the presence of lactic acid bacteria, which favor the occurrence of lactic fermentation, in addition to lactose, which can serve as a substrate for lactic acid bacteria (LAB) present in the ensiled mass, enhancing the fermentation process and, consequently, reducing losses (Rezende et al., 2014; Cruz et al., 2021).

Just as whey is a by-product from milk processing, molasses can be defined as “a product obtained by concentrating sugarcane juice (Saccharum officinarum) or from melted rapadura”; as it is rich in sucrose, it is one of the main fermentation-stimulating additives (Castaño & Villa, 2017). We hypothesized that rehydration of millet grains for silage combined with molasses improves the fermentation profile of the mass and the nutritional value of the silage produced.

Considering the above, the objective was to evaluate the fermentation profile and nutritional value of millet grain silages rehydrated with whey or molasses.

Material and Methods

All animal handling procedures were approved by the Ethics Committee on Animal Experimentation, State University of Montes Claros, Brazil (protocol 215/2020).

The experiment was carried out at the Experimental Farm of the State University of Montes Claros, Janaúba Campus (geographical coordinates: 15° 52′38″S, 43° 20′05″W). The average annual rainfall at the site is less than 700 mm, with an average annual temperature of 28 °C and a relative humidity of approximately 65%. The climate in the region is BSh, according to Köppen (1948).

Four millet rehydration strategies were evaluated, namely, control treatment (rehydration with water), rehydration with whey, rehydration with water and molasses (2.5 g kg^{-1} dry matter, DM), and whey plus molasses (2.5 g kg^{-1} of DM). A completely randomized design with six replications was adopted.

Millet cultivar ADR 500® (ATTO Seeds, Rondonópolis-MT, Brazil) was harvested when the grain moisture content was 11.05%. Millet grains were first ground to a particle size of 1-2 mm. During ensiling, ground millet was rehydrated with clean, chlorine-free water or unsalted whey (NaCl) combined or not with molasses (2.5 g kg^{-1}). Acid whey was obtained from a cheese maker. The volume of acid whey and water required to reach the established 35% moisture level were calculated (Cruz et al., 2021) with the following equation:

$$\Delta\ \text{Liquid (L)} = \frac{\left[\frac{\text{WPMx(FM}-\text{IM)}}{100}-\text{FM}\right]}{\text{SM}},$$

Where, WPM = wet product mass (kg), FM = final moisture; UI = initial moisture; SM = liquid specific mass (kg L^{-1}).

Data on the chemical composition of the acid whey, molasses and millet used, *in natura,* are presented in Table 1. The levels of water and acid whey applied to millet grains were calculated to represent the variation in the DM content generally found in high moisture silages of millet used on farms.

Liquids were mixed with the ground grains, and then ensiled in experimental silos made of Polyvinyl Chloride (PVC) tubes with a capacity of 3.92 L, to obtain a final density of 1,025 ± 50 kg corn grain m^{-3}. Silos were stored in a room and remained closed for 70 days. After opening the silos, recovery DM was calculated as follows:

Recovered DM (%) = [(Fop × DMop)/(Fen × DMen) × 100], where Fop and DMop = forage mass and DM content upon silo opening; Fen and DMen = forage mass and DM content in silage.

Aerobic stability was determined by placing a silage sample (approximately 2 kg) in a mini silo and kept in a non-air-conditioned room with variable temperature (24.0–26.0 °C). Silage temperature was measured every eight hours using a data logger placed at the center of mass for five days. Ambient temperature was also measured using a data collector placed near the mini silos. Aerobic stability was defined as the number of hours the silage temperature remains stable before increasing more than 2°C above room temperature (Kung et al., 2018).

Table 1
Chemical characteristics of the ingredients used in silage production

Item (g kg^{-1})	Acid whey	
pH	5.33	
Acidity (oD)	28.00	
Density at 15ºC	1.024	
Fat	4.00	
Lactose	46.20	
Protein	7.60	
Ash	4.30	
Total solids in fresh milk	67.40	
Total solids in milk post-drying	62.10	
	Molasses	Millet grains
Dry matter	956.6	889.5
Ash	157.9	18.0
Crude protein	27	133.5
Neutral detergent fiber	-	224
Acid detergent fiber	-	72.1
Lignin	-	14.1

Total solids in fresh milk = Practical formula (using density and fat values); Total solids in milk post-drying = using oven drying.

Samples (25 g diluted in 100 mL of distilled water) after silo opening were used to prepare an aqueous extract, according to Kung et al. (2018) to determine pH, ammonia nitrogen (N-NH_3) and organic acids (Pryce, 1969). The pH was measured with a potentiometer (Ak 90, Akso Measuring Instruments, São Leopoldo, RS, Brazil) and the N-NH_3 was measured according to Noel and Hambleton (1976). Volatile fatty acids were determined by liquid chromatography (Shimadzu® Prominence System model 20A, Kyoto, Japan) equipped with a UV-Vis detector set to 210 nm, automatic inlet calibrated for 5 µL sample volume and 300 x RezexTM ROA-Acid Column Organic + 7.8 mm (Phenomenex) kept at 60 °C in an oven. Analytes were diluted with 2.5 mM H2SO4 at a flow rate of 0.6 mL min^{-1}. External standards were used for quantitative calibration purposes.

For chemical composition analysis, part of the silages and ingredients were pre-dried in a forced ventilation oven at 55 °C. Then, all samples were ground in a knife mill with a 1 mm mesh sieve for laboratory analysis. Samples were analyzed for dry matter (INCT-CA G-001/1 and G-003/1), crude protein (INCT-CA N-001/2), ash (INCT-CA M-001/2), neutral detergent fiber (NDF; INCT-CA F-001/2), acid detergent fiber (INCT-CA F-003/2) and lignin (INCT-CA F-005/2) following the recommendations described in Detmann et al. (2021).

For the ruminal kinetics assay, we followed the methodology (Method G-009/1) described by Detmann et al. (2021). Three rumen-cannulated crossbred steers were used, with a mean body weight of 560 ± 27 kg and a mean age of 7 years. Animals were adapted for 14 days to a diet containing 4 kg concentrate (20% crude protein and 70% total digestible nutrients), divided into two meals, in the morning and in the afternoon, in addition to the supply of forage based on millet silage. The roughage: diet concentrate ratio was 80:20 on a DM basis. Water and mineral salt were also provided *ad libitum.*

The in situ degradability technique was adopted using 7.5 x 15 cm non-woven fabric bags (NWF, weight 100) with approximate porosity of 60 µm, according to Casali et al. (2009); the number of samples was determined from the ratio of 20 mg DM.cm-² bag surface area (Nocek, 1988).

Samples were placed in the region of the ventral sac of the rumen for 0, 2, 4, 6, 12, 24 and 48 hours, with the end of the nylon thread tied to the cannula. Bags referring to time zero were not incubated in the rumen, but washed in running water, similar to incubated bags. All samples were removed and washed in cold water to stop ruminal fermentation. Subsequently, samples were oven dried at 55 °C for 120 h and then cooled in a desiccator and weighed. The residues remaining in the NWF bags, collected from the rumen, were analyzed for DM and NDF contents according to the aforementioned methodology. The percentage of degradation was calculated by the proportion of feed remaining in the bags after ruminal incubation.

Data obtained were fit to non-linear regression using the Gauss-Newton method, using the SAS 9.0 software (SAS Institute Inc., Cary, NC), according to the equation proposed by Detmann et al. (2021): $Dt=A+B \times (1-e^{-c \times t})$, where: Y = accumulated degradation of the analyzed nutrient component, after time t; a = intercept of the degradation curve when t = 0, which corresponds to the water-soluble fraction of the analyzed nutritional component;

b = potential for the degradation of the water-insoluble fraction of the analyzed nutritional component; a+b = potential degradation of the analyzed nutrient component when time is not a limiting factor; c = fractional rate of degradation (h^{-1}); t = incubation time. After calculated, coefficients a, b and c were applied to the equation proposed by Detmann et al. (2021): ED=a+(b x c/c+k), where: ED = effective ruminal degradation of the analyzed nutrient component; k = rate of passage of particles through the rumen estimated at 2, 5 and 8% h^{-1} (Agricultural and Food Research Council [AFRC], 1993).

Data were tested by analysis of variance. The Shapiro-Wilk test and the Bartlett test were applied to test residual normality and variance homoscedasticity, respectively. The analysis of variables related to the fermentation profile and nutritional values followed the model:

$$Y_{ijk} = \mu + Reidi + Ino_j + Reid \text{ x } Ino_l + e_{ijk}$$

where:

Y_{ijk} = observation regarding the rehydration source in plot “i” in the absence and presence of inoculant in plot “j” in repetition “k”;

μ = constant associated with all observations;

Reidi= Effect of the rehydration source “i”, with i = 1 and 2;

Inoi = Effect of absence and presence of inoculant “j”, with i = 1 and 2;

Reid x Inol = Effect of the interaction of the level “i” of the rehydration source with the level “j” of the inoculant;

eijk = experimental error associated with plots that, by hypothesis, have a normal distribution with zero mean and variance δ^2.

The silage aerobic stability was analyzed following a split plot completely randomized design with four treatments (plots) and six times after opening (subplots) with six replications. The following statistical model was used:

$$Y_{ijkl} = \mu + Reid_i + Ino_j + e_{ij} + Time_k + Reid_i \text{ x } Ino_l + Reid_i \text{ x } Time_k + Ino_l \text{ x } Time_k + Reid_i \text{ x } Ino_l \text{ x } Time_k + e_{ijkl}$$

where:

Yijk = observation regarding the rehydration source in plot “i” in the absence and presence of inoculant in plot “j” in repetition “l”;

μ = constant associated with all observations;

Reidi= Effect of the rehydration source “i”, with i = 1 and 2;

Inoi = Effect of absence and presence of inoculant “j”, with i = 1 and 2;

Time k = Effect of time after opening the silage “k”, with k=1, 2, 3, 4, 5 and 6;

Reid x Inol = Effect of the interaction of level “i” of the rehydration source with level “j” of the inoculant;

Reid x Time k = Effect of the interaction of level “i” of the rehydration source with level “k” of the time after opening;

Inol x Time k = Effect of the interaction of level “j” of the inoculant with level “k” of the time after opening;

eijkl = experimental error associated with plots that, by hypothesis, have a normal distribution with zero mean and variance δ^2.

When significant by the F test, means of the treatments were compared by Tukey’s test. For all statistical procedures, α = 0.05

was used as the maximum tolerable limit for type I error.

Results and Discussion

Silages added with whey and molasses had higher ($p < 0.05$) DM content compared to control silages (Table 2). Although the control silage had a lower percentage of DM, all the evaluated silages had moisture content within the recommended range for fermentation processes in rehydrated silages, which is between 30-35% (Rezende et al., 2014; Cruz et al., 2021). The addition of whey to silages, regardless of the addition of the other additive, resulted in an increase ($p < 0.05$) in the mineral fraction. This increase is due to the contribution of this fraction (0.43%) present in whey, which is higher than its concentration in water. The CP, NDF, ADF and lignin contents in silages were not influenced by the additives ($p > 0.05$).

Table 2
Chemical composition of millet grain silages ground and rehydrated with a solution containing whey and molasses

Item (g kg^{-1})	Control	Acid whey	Molasses	Acid whey and Molasses	SEM	p-value
Dry matter	663.7 b	675.0 a	673.8 a	678.5 a	2.0	<0.01
Ash	21.5 b	27.5 a	21.6 b	27.3 a	0.50	<0.01
Crude protein	130.7	135.9	136.1	132.5	2.2	0.26
Neutral detergent fiber	166.9	158.2	175.9	167.5	10.9	0.73
Acid detergent fiber	44.5	39.3	36.7	32.8	3.7	0.18
Lignin	12.9	12.8	12.5	12.1	0.4	0.48

Means followed by different letters in the same row are significantly different by Tukey's test ($P<0.05$).
SEM - standard error of the mean; p-value - probability.

The addition of whey or molasses to silages did not influence ($p > 0.05$) the aerobic stability, with an average of 209 h. The high aerobic stability found is possibly related to the low relative humidity of the air during the experimental period, which favored the loss of moisture from silages by evaporation and limited the growth of spoilage microorganisms that produce heat (Cruz et al., 2021), providing longer stability to the studied silages compared to the results reported by Rezende et al. (2014) and M. R. H. Silva et al. (2018). M. R. H. Silva et al. (2018) observed aerobic stability in rehydrated corn silages inoculated with *Lactobacillus buchneri* for 288 h and for the control silage for 71 h. Rezende et al. (2014) evaluated the aerobic stability of rehydrated corn silages with different moisture contents (30, 35 and 40%) and observed longer time for loss of stability in silages with 30% moisture (60 h).

There was no difference ($p > 0.05$; Table 3) in $N\text{-}NH_3$ contents with the use of additives, with an average of 6.04% of total-Nitrogen. The low $N\text{-}NH_3$ content indicates that silages were fermented under suitable conditions, thus inhibiting the growth of proteolytic microorganisms. The N-NH_3 values found in silages are below the percentage of 10% cited by McDonald, Henderson & Heron (1991) as the limit value for a forage plant silage to be considered well preserved. Increasing levels of N-NH_3 may be related to the gradual reduction of the conservation efficiency of the ensiled material, being indicative of proteolysis by undesirable fermenting microorganisms.

Table 3
Aerobic stability and fermentation profile of millet grain silages ground and rehydrated with a solution containing whey and molasses

Item	Control	Acid whey	Molasses	Acid whey and Molasses	SEM	p-value
Aerobic stability (h)	208.00	224.00	192.00	212.00	8.63	0.10
Dry matter recovery (g kg^{-1})	986.40 c	994.60 a	989.50 bc	993.60 ab	1.10	<0.01
pH	4.81a	4.79 a	4.20 b	4.31b	0.09	<0.01
Ammonia nitrogen, % TN	5.81	5.55	7.15	5.67	0.61	0.24

Means followed by different letters in the same row are significantly different by Tukey's test (P<0.05).
SEM - standard error of the mean; p-value - probability.

For pH, lower values ($p < 0.05$) were observed in silages added with molasses (Table 3). The lower pH value for silages containing molasses is due to the increase in soluble substrates (sucrose) in the medium, resulting in higher production of acids, such as lactic acid and, consequently, lower pH. Lower pH values were expected in silages containing additives, since these serve as a source of nutrients for LAB, converting them into acids. It was expected that the silage added with whey would have a lower pH value compared to the control silage, since the whey, in addition to serving as a source of fermentable carbohydrates for LAB, contains lactic acid bacteria (Rezende et al., 2016) that vary according to the process by which the milk was submitted. This directly influences the population of these in the silage, favoring the occurrence of a more efficient acidification by providing greater production of lactic acid compared to other organic acids produced in the silage, such as acetic, propionic, and butyric (McDonald, Henderson & Heron (1991); Cruz et al., 2021).

A higher ($p < 0.05$) lactic acid content was found in silages rehydrated with whey (Table 4), with an average of 1.90% DM. The higher lactic acid content in silages with whey is possibly due to the increase in the LAB population, since whey has a large population of these microorganisms (Rezende et al., 2016). In silages rehydrated with water, even with the addition of molasses, there was a lower production of this acid due to the limited population of LAB. The drying process of grains for storage causes the LAB epiphytic population to be reduced in dry cereal grains, which is proven by the effect of adding microbial inoculants on the fermentation profile of these silages (Kung et al., 2018). The presence of lactic acid in silages is desirable, since this acid is responsible for the rapid decline in pH after closing the silo to values (4.2) that prevent an environment conducive to the development of undesirable microorganisms (Kung et al., 2018).

Table 4
Content of volatile fatty acids and ethanol in millet grain silages ground and rehydrated with a solution containing whey and molasses

Item (% DM)	Control	Acid whey	Molasses	Acid whey and Molasses	SEM	p-value
Lactic acid	10.1 b	19.9 a	8.9 b	18.2 a	1.3	<0.01
Acetic acid	2.5 ab	4.1 a	1.4 b	2.6 ab	0.5	<0.01
Butyric acid	0.0 a	0.0 a	5.7 b	0.0 a	0.0	<0.01
Ethanol	9.9 c	13.6 b	16.2 a	14.9 ab	0.5	<0.01

Means followed by different letters in the same row are significantly different by Tukey's test (P<0.05).
SEM - standard error of the mean; p-value - probability.

For acetic acid contents (Table 4), higher ($p < 0.05$) values were observed in silages rehydrated with whey (0.41%) in relation to silages hydrated with water and molasses (0.14%). Acetic acid has proven antifungal action (D. L. S. Jesus et al., 2019), however the higher content in the silage with whey was not enough to increase aerobic stability in relation to the other treatments. For butyric acid, higher ($p < 0.05$) values were observed in silages rehydrated with water and added with molasses. The higher content of butyric acid in silages with molasses is possibly due to the limited epiphytic LAB population in these silages. The nutritional value of silages is directly affected by the production of butyric acid, which promotes amino acid catabolism and energy loss due to hydrogen production (Muck et al., 2018). The higher ($p < 0.05$) ethanol content in silage containing molasses can be explained by the greater availability of soluble carbohydrates, thus favoring the growth of yeasts, converting this into ethanol.

The additives used did not change ($p > 0.05$) the degradability of fractions A, B and the degradation rate of fractions B and "c" of the DM of the silages, which showed an average of 31.80%, 27.37% and 8.56% h, respectively. The potential degradability (PD) and the undegradable fraction (IF) of DM were also not influenced ($p > 0.05$) by the addition of whey and molasses in millet silages (Table 5). Millet silages with additives showed no differences ($p < 0.05$) for effective degradability at 2% h^{-1} (52.48%) and 5% h^{-1} (47.36%), however for effective degradability at 8% h^{-1} (EDVIII), silages that were added with whey or with molasses had an average DEVIII of 46.43%, differing from the control silage (EDVIII= 41.53%). The time for colonization (lag time) of dry matter was not influenced by the addition of whey and molasses to silages, with an average of 5.64 hours (Table 5).

Whey and molasses added to millet silages did not change ($p < 0.05$) the degradability of the standardized potentially degradable fraction (Bp), the degradation rate of fraction B for neutral detergent fiber, averaged 13.19% and 13.13%, respectively. Potential intake was also not influenced ($p > 0.05$) by the additives used. The additives used did not affect the effective degradability rate at 2% h-¹, however, for the degradability at 5 and 8% h-¹, they showed differences ($P < 0.05$). For EDV, the silage with the addition of whey (17.31%) showed greater effective degradability compared to the silage added with molasses (14.24%). For EDVIII, silages added with whey and those with molasses presented an average of 17.91% compared to silages with added molasses (14.65%).

Table 5

***In situ* degradability of dry matter and neutral detergent fiber of millet grain silages rehydrated with a solution containing whey and molasses**

Item (%)	Control	Acid whey	Molasses	Acid whey and Molasses	SEM	p-value
			Dry matter			
Fraction A	29.41	34.13	34.32	29.29	1.50	0.06
Fraction B	30.95	24.76	24.49	29.27	3.47	0.49
C (% h^{-1})	7.25	10.75	8.75	7.50	0.30	0.80
Potential degradability	60.36	58.90	58.82	58.57	3.95	0.98
IF	39.63	41.09	41.18	41.43	3.95	0.98
ED_{II}	51.41	52.44	53.93	52.14	2.04	0.84
ED_{V}	44.97	48.39	49.50	46.57	1.25	0.12
ED_{VIII}	41.53 b	46.09 a	46.76 a	43.21 ab	1.02	0.01
Lag time (h)	4.67	8.97	4.96	3.97	2.36	0.47
			Neutral detergent fiber			
Fraction Bp	10.44	14.90	14.16	13.25	1.16	0.09
C (% h^{-1})	10.00	10.00	15.50	17.00	1.00	0.06
Ip	89.55	85.10	85.83	86.74	1.16	0.09
ED_{II}	13.10	16.10	15.46	13.71	0.81	0.08
ED_{V}	15.51 ab	17.31 a	16.79 ab	14.24 b	0.67	0.04
ED_{VIII}	17.03 ab	18.11 a	17.72 a	14.65 b	0.69	0.02

Means followed by different letters in the same row are significantly different by Tukey's test ($P<0.05$).
Fraction Bp – standardized potentially degradable insoluble fraction; C - Degradation rate of fraction B "c" (% h^{-1}); Ip - Indigestible fraction; ED_{II}- Effective degradability (k = 2% h^{-1}); ED_{V}- Effective degradability (k = 5% h^{-1}); ED_{VIII}- Effective degradability (k = 8% h^{-1}); k- rate of passage (AFRC, 1993). SEM - standard error of the mean; p-value - probability.

Conclusion

The use of whey as an additive in millet grain silage improves the fermentation profile and nutritional value of the silage produced. Whey combined with molasses provides better pH values, however, it favors the production of butyric acid and ethanol.

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