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Yeast culture combined with *Lithothamnium* increases the performance of feedlot steers

Cultura de levedura associada com *Lithothamnium* potencializam o desempenho de novilhos confinados

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Highlights

Yeast culture increased the daily body weight gain of feedlot steers.
Apparent feed digestibility increased with the inclusion of yeast culture.
Yeast culture improved feed conversion ratio in feedlot steers.

Abstract

The objective of this study was to evaluate the effectiveness of adding yeast culture (*Saccharomyces cerevisiae*) combined with *Lithothamnium* to the diet of feedlot steers through weight gain, dry matter (DM) intake, apparent DM digestibility, and carcass ultrasonography: T1 - diet with yeast culture (7g animal day^{-1}); T2 - diet with *Lithothamnium* (60g animal day^{-1}); T3 - diet with yeast culture (7g animal day^{-1}) plus *Lithothamnium* (60g animal day^{-1}). Thirty-six ½ Angus Nellore steers, intact males, with an average initial weight of 350 kg and an average age of 11 months, were assigned to a completely randomized design composed of three treatments with six replications; each replication was represented by a pen with two animals. The animals were fed *ad libitum* twice daily, at 6:00 and 17:00 h. The diets consisted of 40% corn silage and 60% concentrate, on a DM basis. The feedlot period was 78 days, with 10 days

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of adaptation and 68 experimental days divided into two periods of 34 days each. The addition of yeast culture combined or not with *Lithothamnium* to the diet resulted in greater average daily gain (1.557 and 1.609 versus 1.440 kg day^{-1}), better feed conversion ratio (6.72 and 6.91 versus 7.57 kg DM kg body weight gain^{-1}), and increased the subcutaneous fat thickness (6.69 and 6.71 versus 5.72 mm). This is because of the higher apparent DM digestibility of the diet (71.11 and 69.32 versus 67.51%) compared to the isolated use of *Lithothamnium.* The addition of yeast culture, combined or not with *Lithothamnium* in the diet of feedlot steers, is recommended to improve animal performance and increase fat deposition in the carcass.
Key words: Carcass traits. DM digestibility. Feed conversion. Growth promoter. *Saccharomyces cerevisiae.* Seaweed salt.

Resumo

Objetivou-se avaliar a eficácia da adição de cultura de leveduras (*Saccharomyces cerevisiae*) associada com *Lithothamnium* à dieta de novilhos confinados por meio do ganho médio diário, consumo de matéria seca (MS), digestibilidade aparente da MS e ultrassonografia de carcaça: T1 – dieta com cultura de levedura (7 g animal dia^{-1}); T2 – dieta com *Lithothamnium* (60 g animal dia^{-1}); T3 – dieta com cultura de levedura (7g animal dia^{-1}) mais *Lithothamnium* (60 g animal dia^{-1}). Foram utilizados 36 novilhos ½ Angus Nelore, machos inteiros, com peso médio inicial de 350 kg e idade média de 11 meses, distribuídos em delineamento inteiramente casualizado, composto por três tratamentos com seis repetições, onde cada repetição foi representada por uma baia com dois animais. Os animais foram alimentados ad libitum, duas vezes ao dia, às 6:00 e às 17:00 horas. As dietas foram constituídas por 40% de silagem de milho e 60% de concentrado em base de matéria seca. O período de confinamento foi de 78 dias, sendo 10 dias de adaptação e 68 dias experimentais, este dividido em dois períodos de 34 dias. A adição de cultura de leveduras associada ou não com *Lithothamnium* à dieta promoveu maior ganho médio diário (1,557 e 1,609 contra 1,440 kg dia^{-1}), melhor conversão alimentar (6,72 e 6,91 contra 7,57 kg MS kg peso vivo dia^{-1}) e aumento da espessura de gordura subcutânea (6,69 e 6,71 contra 5,72 mm). Isso ocorreu devido a maior digestibilidade aparente da MS da dieta (71,11 e 69,32 contra 67,51%) em relação ao uso isolado de *Lithothamnium.* A adição de cultura de levedura associada ou não com *Lithothamnium* na dieta de novilhos confinados é recomendada para melhorar o desempenho dos animais e aumentar a deposição de gordura nas carcaças.
Palavras-chave: Características da carcaça. Conversão alimentar. Digestibilidade da MS. Promotor de crescimento. Saccharomyces cerevisiae. Sal de algas.

Introduction

Some dietary additives, such as probiotics, buffers, and alkalizers, can optimize ruminant production by improving ruminal conditions that allow for better fiber digestion and increased production of short-chain fatty acids, which are important energy sources for the animal. In addition, additives can reduce the emission of methane, a greenhouse gas produced through ruminal fermentation. Since 2006, the European Union, through regulation 1831/2003/EC, has banned the use of antibiotics and other

synthetic additives as growth promoters in animal feed, as well as the import of meat products from animals that received these types of additives in their diet. This has driven the scientific community to seek substances that increase animal production without risks to human health in the consumption of animal protein (Marino & Medeiros, 2015; T. S. Oliveira et al., 2008; Spisso et al., 2009).

Several yeast products have been used as feed additives in Brazil because they are safe, do not leave residues in the meat and, according to Bonato et al. (2015), bring benefits to the health and well-being of animals, providing increased animal performance. Yeasts are unicellular fungi, of which *Saccharomyces* is the main genus, widely used in producing alcoholic beverages and baking through sugar fermentation. Yeast cultures as a fermentative medium are a more recent technology for the use of yeast metabolites since these cultures are composed not only of yeast and its fractions but also of the fermentation medium with its metabolites, which include amino acids, enzymes, organic acids, and B vitamins, which are sources of energy, carbon, and nitrogen for ruminal microorganisms (Alves et al., 2015; P. E. P. de Oliveira et al., 2023; D. S. Oliveira et al., 2024).

Yeast cultures can act directly or indirectly on the fermentative and digestive processes of the rumen, stimulating microbial growth, specifically of lactic acid-consuming bacteria, and restricting problems such as ruminal acidosis. This indirectly stimulates the development of bacteria favorable to ruminants, in addition to improving animal performance and feed digestibility (Neumann et al., 2013; Shurson, 2018).

On Holstein cows supplemented with *Saccharomyces,* B. M. L. Oliveira et al. (2010) reported lower dry matter intake (21.3 versus 21.8 kg day^{-1}) and increased milk production (29.6 versus 29.3 kg day^{-1}) when compared to the control group, attributing the results to better fiber digestion. P. E. P. de Oliveira et al. (2023) demonstrated that yeast culture can replace ionophores in beef cattle diets, resulting in gains in productivity since they observed a higher average daily gain (1.667 versus 1.407 kg day^{-1}) when yeast culture was added to the diet compared to the control group diet, in addition to having shown improvements in the animals' immune system.

Another additive used in ruminant nutrition is *Lithothamnium* (seaweed salt), which is a renewable mineral source that contains a large amount of calcium carbonate and magnesium, among other minerals such as Fe, Mn, B, Ni, Cu, Zn, Mo, and Se (T. V. Melo & Moura, 2009). In addition to being a source of macro and micro minerals for cattle, it has physical and chemical characteristics of high porosity and large surface area, which allows the availability, adsorption, and enhanced absorption of its nutrients in the animal's body.

In a study with dairy cows, seaweed salt had a positive influence on their productivity since animals fed 0.4% kg DM^{-1} of salt had ruminal pH lower than 5.5 for less time (4h) than control animals (13.8h), and those fed sodium bicarbonate at 0.8% kg DM^{-1} (7.5h) on high-energy diets (oat hay 176 g kg^{-1}; alfalfa hay 176 g kg^{-1}; wheat bran 48 g kg^{-1}; soybean meal 74 g kg^{-1}; cottonseed meal 37 g kg^{-1}; fish meal 26 g kg^{-1}; ground corn 400 g kg^{-1}; urea 4 g kg^{-1}; molasses 30 g kg^{-1}; Megalac 20 g kg^{-1}; salt 3 g kg^{-1}; mixture of minerals and vitamins

2 g kg^{-1}), evidencing better ruminal stability (Cruywagen et al., 2015). Furthermore, the use of *Lithothamnium,* despite not having influenced dry matter intake between the groups (average of 24.5 kg day^{-1}), increased milk production to 31.8 kg day^{-1} compared to the group fed sodium bicarbonate and the control group, with 29.1 and 27.6 kg day^{-1}, respectively, and also had its composition changed due to better calcium bioavailability.

Research studies demonstrate that the inclusion of *Lithothamnium* in diets with a high concentrate content for finishing beef cattle controls ruminal pH, that is, it acts as a buffer due to the presence of calcium carbonate, in addition to also acting as an alkalizing agent due to the presence of magnesium-based compounds, increasing animal performance, without interfering with food consumption. Although the use of this additive has been evaluated in other monogastric species, its application in ruminant nutrition, such as beef cattle, is poorly studied, which highlights the need for more research to understand its efficacy and safety in these species (Carvalho et al., 2016; Lima et al., 2023; T. S. Oliveira et al., 2008).

In view of the above, this study aimed at evaluating and comparing the ingestive behavior, apparent digestibility of the diet, productive performance, and carcass traits of feedlot beef steers receiving yeast culture (*Saccharomyces cerevisiae*) combined or not with *Lithothamnium* in the diet.

Material and Methods

The experimental procedures were previously submitted for consideration by the Ethics Committee on Animal Experimentation (CEUA/UNICENTRO) and approved for execution according to official letter 047/2023 dated October 30, 2023.

The experiment was carried out at the Animal Production Center (NUPRAN) of the Agricultural and Environmental Sciences Sector of the Midwestern Paraná State University (UNICENTRO), located in the municipality of Guarapuava, Paraná State, Brazil (25º23'02" S, 51º29'43" W; 1,026 m altitude). The climate of the region is humid mesothermal subtropical (Cfb), with no dry season, cool summers, and moderate winters. According to the Köppen classification, Guarapuava is located at an altitude of approximately 1,100 m, with an average annual rainfall of 1,944 mm, an average annual minimum temperature of 12.7 ºC and an average annual maximum of 23.5 ºC with a relative humidity of 77.9%.

The efficacy of adding yeast (*Saccharomyces cerevisiae*) combined with *Lithothamnium* to the diet of feedlot steers was evaluated using the following treatments: T1 – diet with yeast culture (7 g animal day^{-1}); T2 – diet with *Lithothamnium* (60 g animal day^{-1}); T3 – diet with yeast culture (7 g animal day^{-1}) plus *Lithothamnium* (60 g animal day^{-1}).

The Cultron® product, from the Aleris Nutrition company, is a yeast culture (*Saccharomyces cerevisiae*) obtained from the fermentation of cereals from the ethanol industry, using the "Ethanol red®" strain in a controlled nutrient medium containing sugarcane molasses and corn derivatives, in which the fermentation medium is dried together with the yeast after alcohol extraction. Its full composition has 920 g kg^{-1} of dry matter (DM), 450 g kg^{-1} of crude protein (CP), 50 g kg^{-1} of ether extract (EE), 70 g kg^{-1} of

crude fiber, 40 g kg^{-1} of mineral matter (MM), 0.50 g kg^{-1} of Ca, 7.80 g kg^{-1} of P, 3.80 g kg^{-1} of K, 150-170 g kg^{-1} of β-glucans, 80-100 g kg^{-1} of mannan oligosaccharides, in addition to fermentation metabolites with different amino acids, vitamins, enzymes and organic acids.

The *Lithothamnium*-based product used was LithoNutri® (composed basically of highly bioavailable calcium due to its plant-based origin), produced by the company Oceana Minerais Marinhos Ltda., registered with MAPA under number MA A – 06267 00001-6, and classified as an ingredient for animal feed (moisture: 40 g kg^{-1}, mineral matter: 930 g kg^{-1}, and Ca: 320 g kg^{-1}).

The silage used to feed the animals was produced from the harvest of corn plants 140 days post-emergence, at the dent phenological stage (R5), with the aid of a forage harvester JF® model (C-120 AT S2). The cutting height was 25 cm and the harvester was set to an average particle size with a proportion of 7.8% on the first sieve (>1.91 cm), 56.8% on the second sieve (1.91-0.78 cm) and 35.4% on the third sieve (<0.78 cm), generating an average particle size of 1.15 cm. The harvested material was transported, placed in a previously leveled and well-drained location, and deposited in thin layers in three "semi-trench" silos. Compaction was performed with a tractor to obtain a density of 210 kg of DM m^{-3}. Subsequently, the silos were completely sealed with a 200 µm double-sided tarpaulin. The ensiling time in each silo was 12 hours, on average. The experimental silo was unloaded during 78 days of feedlot animal feeding, with daily removal of 20 cm from the silo feed-out panel.

Thirty-six ½ Angus ½ Nellore steers, intact males, from the same herd, with an average initial weight of 350 kg and an average initial age of 11 months, were previously dewormed, and housed in 18 semi-covered confinement pens, with an area of 15 m^2 each (2.5 m × 6.0 m). Each pen had a concrete feeder measuring 2.30 m long, 0.60 m wide, and 0.35 m deep, and a metal drinker regulated by a float. At night, the pens were illuminated with artificial light.

The distribution of animals in the experimental units was based on body weight (BW), ribeye area (REA), marbling index, and rump cap fat thickness (RFT), determined by ultrasound (Aloka® SSD-500 Vet) consisting of an echo camera coupled to a 17 cm, 3.5 MHz probe. The animals were distributed in the treatments as evenly as possible considering these four criteria. Therefore, the experimental design was completely randomized, consisting of three treatments with six repetitions, in which each pen with two animals represented an experimental unit.

The experimental period was 78 days, with 10 days of adaptation and 68 experimental days, the latter divided into two periods of 34 days. The animals were fed twice a day, at 6:00 and 17:00 h, with a total mixed ration (TMR) composed of 400 g kg^{-1} of corn silage and 600 g kg^{-1} of concentrate, on a DM basis (Table 1). The concentrate was prepared at the commercial feed factory of Cooperativa Agrária (Guarapuava, Paraná, Brazil), formulated based on soybean meal (50.0 g kg^{-1}), ground corn grain (318.5 g kg^{-1}), corn germ (100.0 g kg^{-1}), wheat bran (240.0 g kg^{-1}), soybean hulls (82.2 g kg^{-1}), malt radicle (160.0 g kg^{-1}), calcitic limestone (27.0 g kg^{-1}),

livestock urea (8.1 g kg^{-1}), common salt (6.0 g kg^{-1}) and vitamin-mineral premix (8.3 g kg^{-1}), and was supplied as pellets. The additives were homogenized in 100 grams of ground concentrate, creating a uniform mixture, to facilitate the delivery of treatments on the feed provided in each pen at each meal. Voluntary intake was recorded daily by weighing the amount of feed offered and leftovers from the previous day, and adjustments were made daily to maintain leftovers at 5% of the DM of the feed provided.

Table 1
Chemical composition of corn silage and concentrate and average values in the experimental diet, on a total dry matter basis

Chemical composition	Corn silage	Concentrate[a]	Experimental diet
Dry matter, g kg^{-1} natural matter	290.4	892.9	651.9
Mineral matter, g kg^{-1} DM	41.1	81.1	65.1
Crude protein, g kg^{-1} DM	71.6	161.3	125.4
Ether extract, g kg^{-1} DM	29.3	39.2	35.3
Starch, g kg^{-1} DM	342.3	386.4	368.7
Neutral detergent fiber, g kg^{-1} DM	463.6	268.3	346.5
Acid detergent fiber, g kg^{-1} DM	309.8	96.0	181.5
Lignin, g kg^{-1} DM	46.4	13.6	26.7
Total digestible nutrients, g kg^{-1}	661.6	813.4	752.7

[a] Premix guaranteed level per kg of concentrate: vit. A: 14,000 IU; vit. D3: 1,800 IU; vit. E: 75 IU; Monensin sodium: 40 mg; S: 0.70 g; Mg: 0.12 g; Na: 3.0 g; Co: 1.0 mg; Cu: 18 mg; I: 1.1 mg; Mn: 29.0 mg; Se: 0.35 mg; and Zn: 72.2 mg.

Composite samples of corn silage and concentrate were taken each week during the feedlot period to determine their chemical composition. The samples were dried in a ventilated oven at 55 °C for 72 hours and ground in a Wiley mill with a 1-mm mesh sieve. The analyses of DM, CP, MM, and EE were performed according to Association of Official Analytical Chemists [AOAC] (1995). The neutral detergent fiber (NDF) contents were obtained according to the method of Van Soest et al. (1991) with thermostable α-amylase and acid detergent fiber (ADF) according to Goering and Van Soest (1970). The estimate of total digestible nutrients (TDN) was obtained according to Weiss et al. (1992). Starch analysis was performed based on the hydrolysis of the starch in the sample (Hendrix, 1993), after extraction of soluble carbohydrates with successive washes in 80% alcohol and colorimetric analysis of reducing sugars (glucose), with subsequent conversion of the result into starch.

The animal ingestive behavior was analyzed continuously for 96 hours between experimental days 33 and 37, starting at noon on the first day and ending at noon on the last day of evaluation. The observations

were made by 6 observers taking turns every 6 hours, at regular intervals of 3 minutes. Data on ingestive behavior, represented by the activities of feeding, ruminating, drinking, and idling, were expressed in hours day^{-1}. Furthermore, following the same observation methodology, the frequency of feeding, drinking, urinating, and defecating activities was counted and expressed as the number of times per day. During the nighttime, the environment was kept under artificial lighting.

In addition to the ingestive behavior, the apparent digestibility of DM (DDM) of the diet was determined. For this purpose, composite samples of the diets of each treatment were formed during the experimental period. Feed collections were performed once a day, following the methodology of collecting for four consecutive days, and stored in a freezer. After the end of the evaluation, samples were thawed, homogenized to a composite sample, per pen and treatment, and stored at -15 °C. In addition, the daily food intake and leftovers were measured for four consecutive days (96 hours), together with the total collection of feces produced by the animals in each pen. During the apparent digestibility trial, a homogeneous sample of the feces produced was collected from each experimental unit at the end of each 6-hour shift and stored under refrigeration at -15 °C to be analyzed after the evaluation of the ingestive behavior. After four consecutive days of collection, these were mixed and homogenized to a composite sample for laboratory analysis of the apparent digestibility of starch (DS) and neutral detergent fiber (DNDF). The weight of the fecal sample collected at the end of each 6-hour interval was proportional to the total volume of feces produced by the experimental unit.

The DM of the leftovers and feces of each experimental unit were determined using the same procedures adopted in the diet analysis. The DDM was calculated using the following formula: DDM (%) = [(DM ingested – DM excreted) / DM ingested] × 100.

The fecal score of each pen was analyzed daily based on the methodology adapted from Looper et al. (2001) and Ferreira et al. (2013), with a scale ranging from 1 to 6, as follows: 1 = watery feces, not very consistent; 2 = runny feces, not very consistent, with small piles of up to 2.5 cm; 3 = pasty feces with concentric rings and piles of 3 to 4 cm (considered ideal); 4 = soft liquid feces with concentric rings and piles of more than 5 cm; 5 = drier feces without concentric rings and piles of more than 5 cm; and 6 = hard or dry feces.

The animals were weighed at the beginning of the adaptation period, on experimental days 0, 34, and 68 (last day) after a 12-hour solid fast. The diets and leftovers were weighed daily to determine the daily DM intake, expressed in kg day-1 (DMI) or as a percentage of body weight (DMIBW). The average daily gain (ADG) and DMI data were used to calculate the feed conversion ratio (FCR).

At the end of the experimental period, assessments were made of the REA, marbling, subcutaneous fat thickness of the *Longissimus dorsi* muscle, and RFT using an echo camera (Aloka® SSD-500 Vet) coupled to a 17 cm, 3.5 MHz probe. The measurements were taken between the 12th and 13th ribs, across the *Longissimus dorsi* muscle, as proposed by Herring et al. (1994). From the REA measurements, the ratio was calculated,

which represents the relationship between REA height and width. The images were interpreted by the laboratory responsible for data quality assurance (Designer Genes Technology) using the "BIA/DGT Brasil" software. Marbling was assessed by the presence of visible white flecks between muscle fibers in the *Longissimus dorsi* and scored using indices ranging from 1 (non-existent) to 5 (excessive) adapted from the system proposed by Müller (1987).

The data were subjected to statistical analysis using the Statistical Analysis System Institute [SAS Institute] (1993). The UNIVARIATE procedure was applied to evaluate the presence of outliers and remove them from the database. Then, the data were tested by ANOVA using the GLM procedure, adopting a significance level of 10% ($P \leq 0.10$). The following statistical model was used:

$$Y_{ijk} = \mu + \alpha_i + \varepsilon_{ij}$$

where: Y_{ij} = dependent variables; μ = overall mean of all observations; α_i = Effect of treatments of order "i", in which 1 = diet with yeast culture; 2 = diet with *Lithothamnium*; 3 = diet with yeast culture and *Lithothamnium*, and ε_{ij} = residual random effect. When the treatment effect was significant, the means were compared using the Tukey test at 10% significance.

Results and Discussion

In general, the ingestive behavior of feedlot steers (expressed in hours day^{-1} and number of times day^{-1}) remained stable, with no changes when yeast culture was included in the diet, combined or not with *Lithothamnium* (Table 2). According to L. D. Melo et al. (2023), the inclusion of additives in the diet alone does not allow changes in the behavior of the animals, which is an advantage, since certain behavioral changes can influence intake, decrease weight gain, and even food selection. Factors that can influence the ingestive behavior of cattle are related to the physical composition of the diet, such as fiber content and particle size, which are directly associated with rumination time and ingestion. Since the diets of the different treatments were the same, this may be the main reason why there were no statistical differences in the behavioral evaluation.

Table 2
Ingestive behavior, expressed in hours day^{-1} and number of times day^{-1}, of feedlot steers receiving yeast culture combined or not with *Lithothamniun* in the diet

Parameter	Experimental diet			Mean	SEM	P-value
	Yeast culture	*Lithothamniun*	Combination			
Hours day^{-1}:						
Feeding	2:35	2:46	2:33	2:38	0.156	0.6514
Drinking	0:16	0:14	0:16	0:15	0.015	0.8931
Ruminating	5:02	4:30	5:06	4:58	0.068	0.9122
Idling	16:06	16:13	16:14	16:11	0.626	0.5087
Times day^{-1}:						
Feeding	14.8	14.61	14.14	14.50	0.923	0.8851
Drinking	5.4	4.47	6.05	5.31	0.554	0.1773
Defecating	6.9	7.08	6.61	6.86	0.423	0.8956
Urinating	5.3	4.94	5.03	5.08	0.405	0.8202

SEM: standard error of the mean.

Fecal output (kg day^{-1}), both in DM and in natural matter (MN), fecal DM content, fecal score, and pH did not change (P>0.05) with the inclusion of yeast culture combined or not with *Lithothamnium* in the diet of feedlot steers (Table 3). Silva et al. (2012) show that some fecal parameters are influenced by the levels of energy, starch, and fiber present in the diet. Since the composition of the diet was the same between treatments, as the diet was balanced regarding the presence of starch and NDF, there was no statistical difference in the fecal parameters.

Table 3
Fecal output in kg day^{-1}, on a natural or dry matter basis, dry matter (DM) content, fecal score and pH, and apparent digestibility of dry matter (DDM), starch (DS), and neutral detergent fiber (DNDF) of the feed supplied to feedlot steers with the addition of yeast culture combined or not with *Lithothamniun* in the diet

Parameter	Experimental diet			Mean	SEM	P-value
	Yeast culture	*Lithothamnium*	Combination			
Feces (kg MN day^{-1})	16.22	16.06	15.93	16.07	0.78	0.9665
Fecal DM (%)	16.76	17.74	17.32	17.27	0.31	0.1210
Fecal starch (%)	1.60	1.77	1.47	1.61	0.11	0.2216
Fecal NDF (%)	51.66	52.23	52.56	52.15	1.018	0.8209
Feces (kg DM day^{-1})	2.72	2.81	2.77	2.77	0.12	0.8487
Fecal score	2.88	2.96	2.87	2.90	0.05	0.4066
Fecal pH	8.15	8.18	8.01	8.11	0.09	0.4049
DDM (%)	71.11 a	67.51 b	69.32 ab	69.31	0.60	0.0027
DS (%)	98.55	98.29	98.51	98.45	0.09	0.4049
DNDF (%)	54.20 ab	51.07 b	56.29 a	53.85	1.18	0.0220

[a-b] Means followed by different letters, in the same row, are significantly different by Tukey's test at 10%.
SEM: standard error of the mean.

There were no differences (P>0.05) between the treatments evaluated for fecal starch content and DS, with mean values of 1.61% and 98.45%, respectively (Table 3). However, the dietary inclusion of yeast culture led to an increase (P<0.05) in DDM (71.11%) compared to the diet with isolated inclusion of *Lithothamnium* (67.51%); and the diet with the combination of yeast culture and *Lithothamnium* showed intermediate and similar values (69.32%). The fecal NDF content did not present a statistical difference (P>0.05) between the evaluated treatments, with an average value of 52.15%; however, the apparent digestibility of NDF of the treatment with the combination of yeast culture with *Lithothamnium* presented a higher value (P<0.05) compared to the treatment of *Lithothamnium* alone, with levels of 56.29% and 51.07%, respectively; the content of the isolated yeast culture was intermediate (P>0.05) to the other treatments. According to Neumann et al. (2020), the use of yeast culture can stabilize ruminal pH, and improve fiber digestibility and, consequently, the use of nutrients, characteristics that can be evidenced by the better DDM of the treatment with the isolated use of yeast culture. Due to the composition of *Lithothamnium,* it acts as a buffer in diets high in concentrate (70%), which stabilizes the ruminal pH, and improves the digestibility of the fiber portion of the diet (T. V. Melo & Moura, 2009; C. A. S. Rossi, 2019). These characteristics added to the benefits of the yeast culture are evidenced by the higher DNDF values presented by the combination of the additives and intermediate DDM values. Furthermore, according to Petri et al. (2012), when the pH is below 6, the medium becomes harmful to cellulolytic bacteria, causing their

mortality. Thus, as both additives tested in the experiment can modulate the ruminal pH, this suggests an increase in the amount of fiber-degrading bacteria, evidenced by the higher DNDF of the treatment with the combination.

After 68 feedlot days, animals that had yeast culture included in their diet, combined or not with *Lithothamnium,* presented higher (P<0.05) ADG (1.609 and 1.557 versus 1.440 kg day^{-1}) and better FCR (6.44 and 6.72 versus 7.57 kg DM kg gain^{-1}) compared to the diet with isolated inclusion of *Lithothamnium,* respectively. For DMI and DMI$_{BW}$, no significant changes (P>0.05) were detected between the different treatments. According to B. M. L. Oliveira et al. (2010), yeast stimulates the development of cellulolytic bacteria, which increases ruminal degradability and DDM, which justifies the higher ADG and lower FCR of the treatments with yeast culture (Table 4). The improvement in ADG and FCR of the animals receiving yeast culture also resulted in greater total weight gain at the end of the experiment (Table 5). According to P. E. P. de Oliveira et al. (2023), better feed digestibility can increase the production of short-chain fatty acids and consequently decrease methane production; also, propionic acid, recognized as an efficient energy source for ruminants and a precursor of glucose, provides more metabolizable energy from the feed to the animal (Gonçalves et al., 2012). This is evidenced by the better ADG and FCR of animals receiving yeast culture or the combination of additives.

Table 4
Average daily gain (ADG), dry matter intake expressed in kg day^{-1} (DMI) or per 100 kg of body weight (DMI$_{BW}$), feed conversion ratio (FCR) of feedlot steers receiving yeast culture combined or not with *Lithothamniun* in the diet

Parameter	Experimental diet			Mean	SEM	P-value
	Yeast culture	*Lithothamniun*	Combination			
ADG, kg day^{1}:						
0 to 34 days	1.574 a	1.409 b	1.620 a	1.534	0.053	0.0220
0 to 68 days	1.557 a	1.440 b	1.609 a	1.535	0.065	0.0078
DMI, kg day^{-1}:						
0 to 34 days	9.35	8.85	9.02	9.07	0.23	0.3325
0 to 68 days	9.55	9.11	9.24	9.30	0.26	0.4815
DMI$_{BW}$, % body weight:						
0 to 34 days	2.50	2.36	2.41	2.43	0.05	0.1346
0 to 68 days	2.36	2.25	2.27	2.29	0.04	0.1793
FCR, kg DM kg^{-1} gain:						
0 to 34 days	7.10 b	8.55 a	6.93 b	7.53	0.33	0.0258
0 to 68 days	6.72 b	7.57 a	6.44 b	6.91	0.35	0.0298

[a-b] Means followed by different letters, in the same row, are significantly different by Tukey's test at 10%.
SEM: standard error of the mean.

Other advantages of yeast and its byproducts are related to animal health issues, as reported by Zdepski et al. (2023), who evaluated the immunity, and rumen and intestinal health of feedlot steers fed yeast culture and autolyzed yeast and reported that yeast cultures reduced the changes in the ruminal papillae by 30% when compared to the other groups. The yeast culture promoted an improvement in the animals' immune response, given the reduction in papillae inflammation, evidenced by the reduced infiltration of neutrophils in the rumen walls. These characteristics are related to better absorption of nutrients by ruminal papillae, increasing the productive performance of cattle. Beneficial characteristics on animal health, in addition to being associated with better feed digestibility, are evidenced by the better performance of the groups treated with yeast culture alone or combined with *Lithothamnium.*

Table 5
Initial and final body weight, mean final values and gain during the feedlot period, and ultrasonographic characteristics of rib eye area (REA), ratio, marbling, subcutaneous fat thickness (SFT), and rump cap fat thickness (RFT) of feedlot steers receiving yeast culture combined or not with *Lithothamnium* in the diet

Parameter	Experimental diet			Mean	SEM	P-value
	Yeast culture	*Lithothamniun*	Combination			
Initial weight, kg	350.8	349.3	349.4	349.8	5.7	0.9793
Final weight, kg	458.3 a	448.4 b	460.5 a	455.7	7.0	0.0426
Total weight gain, kg	107.5 a	99.2 b	111.2 a	105.9	4.6	0.0394
Final:						
. REA	82.03	79.96	81.38	81.13	2.33	0.8123
. Ratio	0.55	0.54	0.52	0.54	0.01	0.5307
. Marbling	3.39	3.28	3.34	3.34	0.10	0.7575
. SFT (mm)	6.69 a	5.72 b	6.71 a	6.37	0.41	0.0932
. RFT (mm)	9.05 a	8.28 b	8.84 a	8.73	0.38	0.0597
Gain in the period:						
. REA	18.29	17.70	18.56	18.18	1.56	0.9249
. Ratio	0.05	0.05	0.04	0.05	0.01	0.4869
. Marbling	0.60	0.55	0.63	0.59	0.04	0.9130
. SFT (mm)	3.90 a	2.53 b	3.30 a	3.04	0.19	0.0896
. RFT (mm)	4.30 a	3.40 b	4.03 a	3.91	0.28	0.0502

a-b Means followed by different letters, in the same row, are significantly different by Tukey's test at 10%.
SEM: standard error of the mean.

Animals that received yeast culture combined or not with *Lithothamnium* in the diet had higher BW at the end of the feedlot period (460.5 and 458.3 versus 448.4 kg), showing superior efficiency in fattening animals compared to the diet with *Lithothamnium,* respectively (Table 5). There was no influence (P>0.05) of the diets with yeast culture combined or not with *Lithothamnium* on the carcass traits measured by ultrasonography at the end of the evaluation period or on the gain during the period, rib eye area, ratio, and marbling. The use of yeast culture combined or not with *Lithothamnium* showed higher values (P<0.10) on the parameters of SFT (3.90 mm and 3.30 mm versus 2.53 mm) and RFT (4.30 mm and 4.03 mm versus 3.40 mm), compared to the diet that included only *Lithothamnium,* respectively. According to Rigobelo et al. (2014), some factors influence carcass traits such as breed, age, sex, and nutrition; however, energy levels in the diet are what most influence fat deposition. Another factor that may justify the lack of changes in the ultrasonographic characteristics of the carcass is the short finishing period, which was 68 days. Santos et al. (2001) reported that the increase in DNDF is responsible for increasing the proportion of acetate in the rumen; this short-chain fatty acid is the main precursor of fat in the animal. Thus, it is possible to explain that greater fat deposition is achieved with treatments that lead to greater apparent digestibility of DM and NDF.

Conclusion

The addition of yeast culture combined or not with *Lithothamnium* to the diet for feedlot steers promoted greater average daily gain, better feed conversion ratio, higher dry matter digestibility, and increased subcutaneous fat thickness compared to the diet included with *Lithothamnium* alone. Thus, the addition of yeast culture combined or not with *Lithothamnium* to the diet is recommended to increase the performance and improve the finishing of carcasses of feedlot steers.

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