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Effect of yeast culture combined with sodium monensin on the productivity and health of feedlot cattle

Efeito da cultura de levedura associada à monensina sódica na produtividade e saúde de bovinos confinados

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Highlights

Yeast culture resulted in greater weight gain and better carcass finishing.
The inclusion of yeast culture improved the apparent digestibility of DM and NDF.
Sodium monensin was inferior for DMI compared to the other treatments.

Abstract

The inclusion of ionophores and/or natural additives in animal feed, supplied alone or in combination, can bring benefits during the productive periods of beef cattle production. The experiment was conducted at the Animal Production Center (NUPRAN) facilities at the Master's Degree in Veterinary Sciences of the Agricultural and Environmental Sciences Sector of UNICENTRO, in Guarapuava, State of Paraná. The aim was to evaluate the productive performance, ingestive behavior, apparent digestibility of the concentrate, and carcass traits of steers finished in confinement receiving yeast culture (*Saccharomyces cerevisiae*) combined or not with sodium monensin in the diet: MON–diet with sodium monensin (250 mg animal

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day^{-1}); CUL–diet with yeast culture (7 g animal day^{-1}); and MON + CUL–diet with yeast culture and sodium monensin (7 g animal day^{-1} + 250 mg animal day^{-1}). Thirty-six whole steers, ½ Angus Nellore, with an average initial body weight of 416 kg, were used in the experiment. Steers fed yeast culture showed higher values for average weight gain (1.6144 kg day^{-1}), improvements in carcass finishing, better capacity to convert ingested DM into carcass gain (9.34 day^{-1}), apparent digestibility of DM (72.37%) and NDF (48.28%) compared to animals on sodium monensin. The combination demonstrated intermediate values for DMI (10.10 kg day^{-1}), hindquarter fat thickness (6.67 mm), and rump fat thickness (5.24 mm). Sodium monensin resulted in intermediate values for DMD (71.73%), and forequarter fat thickness (3.58 mm). Using yeast culture promoted greater average weight gain, better carcass finishing, and better capacity to transform ingested DM into carcass gain, because of improvements in the apparent digestibility of DM and NDF compared to the diet with sodium monensin.
Key words: Carcass finishing. Digestibility of dry matter and neutral detergent fiber. Weight gain. *Saccharomyces cerevisiae* yeast culture.

Resumo

A utilização de ionóforos e/ou aditivos naturais na alimentação animal fornecidos individualmente ou em associação pode trazer benefícios nos parâmetros produtivos da produção de bovinos de corte. O experimento foi realizado nas instalações do Núcleo de Produção Animal (NUPRAN) junto ao Curso de Mestrado em Ciências Veterinárias do Setor de Ciências Agrárias e Ambientais da UNICENTRO, em Guarapuava-PR. O objetivo foi avaliar o desempenho produtivo, o comportamento ingestivo, a digestibilidade aparente do concentrado e as características de carcaça de novilhos terminados em confinamento com cultura de levedura (Saccharomyces cerevisiae) associado ou não a monensina sódica à dieta alimentar: MON – dieta com monensina sódica (250 mg animal dia^{-1}); CUL – dieta com cultura de leveduras (7g animal dia^{-1}); e MON + CUL – dieta com cultura de leveduras e monensina sódica (7g animal dia^{-1} + 250 mg animal dia^{-1}). Utilizou-se no experimento 36 novilhos inteiros, ½ sangue Angus Nelore e peso vivo médio inicial de 416 kg. A cultura de levedura obteve valores superior para ganho médio de peso (1,6144 kg dia^{-1}), melhorias no acabamento de carcaça, melhor capacidade de transformação de MS ingerida em ganho de carcaça (9,34 kg dia^{-1}), digestibilidade aparente da MS (72,37%) e da FDN (48,28%) em relação a dieta com monensina sódica. A associação demonstrou valores intermediários para CMS (10,10 kg dia^{-1}), espessura de gordura de traseiro (6,67 mm) e espessura de gordura de picanha (5,24 mm). A monensina sódica obteve valores intermediários para DMS (71,73 %) e espessura de gordura de dianteiro (3,58 mm). O uso de cultura de levedura promoveu maior ganho médio de peso, maior acabamento de carcaça e melhor capacidade de transformação da MS ingerida em ganho de carcaça, devido as melhorias na digestibilidade aparente da MS e da FDN em relação a dieta com monensina sódica.
Palavras-chave: Acabamento de carcaça. Cultura de levedura de *Saccharomyces cerevisiae.* Digestibilidade de matéria seca e fibra em detergente neutro. Ganho de peso.

Introduction

In the production chain of food of animal origin, there is a constant search for food additives that can improve animal performance, thereby increasing the profitability of the production system while respecting animal welfare and the environment (Vohra et al., 2016).

However, to achieve efficiency, especially in the fattening phase, it is necessary to incorporate concentrates into the diets but the inclusion of higher levels of energy can cause digestive disorders, due to the high fermentability of the ingredients used (T. I. Silva et al., 2023). Therefore, it is necessary to include some food additives to minimize these negative effects and simultaneously improve feed efficiency, and weight gain and even have positive environmental impacts by reducing methane emissions, such as sodium monensin, for example (T. I. Silva et al., 2023).

Sodium monensin is produced by the fermentation of *Streptomyces canelaensis* and is the most widely used ionophore in commercial beef cattle production due to its ability to alter ruminal fermentation patterns and improve feed efficiency (Meyer et al., 2009). In the rumen, sodium monensin increases propionate synthesis and reduces ruminal accumulation of methane, ammonia, and lactate (*Streptococcus bovis* and *Lactobacillus* spp.), promoting diet digestibility and nutrient utilization. It also contributes to pH stabilization, reducing variation in dry matter intake while limiting intake (Callaway et al., 2003).

However, monensin has been criticized by the European Union and raised concerns about its involvement in bacterial resistance. However, its main role is to control parasitic infections caused by coccidia in animals and improve feed efficiency (Carresi et al., 2024). Therefore, the meat production chain has been seeking alternatives for it, as well as associations to maximize products (Samuelson et al., 2016).

As a result, yeasts have been gaining prominence, including *Saccharomyces cerevisiae,* which is the most widely used yeast in animal feed, and there are different ways in which they can be used to control or modify the ruminal fermentation pattern (Huebner et al., 2019). However, the present study uses yeast culture, which is conceptualized as a dry product composed of yeast and its entire growth medium, which contains the combination of yeasts and their parts added to the biomass from the process and the metabolites generated in the fermentation process (Shurson, 2018; Poppy, 2008).

The ultimate goal is a compound with lysed cells, yeast walls, organic acids, malate, polyphenols, antioxidants, peptides, nucleotides, phytosterols, mannans, and beta-glucans, in addition to the metabolites generated in the fermentation process, which may or may not have live cells (Alves et al., 2015). These characteristics contribute to improved ruminal function, with greater fiber degradation and microbial protein synthesis, and alleviate the accumulation of lactate and ammonia in the rumen (Desnoyers et al., 2009; Gaggìa et al., 2010; Shurson, 2018).

According to Erasmus et al. (2009) and Frumholtz et al. (1992), there may be additive and/or associative effects between yeast culture and ionophores. The culture can neutralize the reduction in dry matter

intake caused by ionophores, thus reducing the depressant effect on milk production or weight gain, through fiber digestibility (favoring fibrolytic bacteria by the culture) and ionophores (due to inhibition of the growth of lactic acid-producing bacteria), maintaining a more stable ruminal pH.

It is hypothesized that some analogous characteristics of sodium monensin and yeast culture when used in combination, may enhance the productive characteristics of animals. In addition, the combination of different feed additives is a common practice in the nutrition of beef cattle, although the additive effects of these supplements have not been clearly described in the literature.

The objective of this study was to evaluate the productive performance, ingestive behavior, apparent digestibility of the diet, and carcass traits of feedlot-finished beef steers receiving yeast culture combined or not with sodium monensin in the diet.

Material and Methods

Location

The experiment was conducted at the State University of the Midwestern region, Master's Degree in Veterinary Sciences of the Agricultural and Environmental Sciences Sector and the Animal Production Center (NUPRAN), located in Guarapuava, State of Paraná, Brazil.

The climate of the Guarapuava region is humid mesothermal subtropical (Cfb), with no dry season, cool summers, and moderate winters. According to the Köppen classification, Guarapuava has an altitude of approximately 1,100 m, an average annual rainfall of 1,944 mm, an average minimum annual temperature of 12.7ºC and an average maximum annual temperature of 23.5ºC with a relative humidity of 77.9%.

CEUA

All experimental procedures were previously submitted to the Animal Research Ethics Committee for Animal Experimentation (CEUA/UNICENTRO) and approved with protocol 0005/2022, of 11/04/2022.

Thirty-six ½ Angus Nellore steers, with an initial average body weight of 416 kg and an average age of 14 months were previously dewormed. The experiment was completely randomized consisting of three treatments: MON–diet with sodium monensin (250 mg Rumensin 200® animal day^{-1}); CUL–diet with yeast culture (7g Cultron® animal day^{-1}); and MON+CUL–diet with yeast culture plus sodium monensin (7g animal day^{-1} + 250 mg animal day^{-1}).

Animals were distributed in the experimental units, represented by pens, considering body weight (BW), loin eye area (LOA), marbling, and fat thickness of the rump cap (FAT), determined by ultrasound (Aloka® SSD-500 Vet) consisting of an echo camera coupled to a 17 cm, 3.5 MHz probe. The images were interpreted by the laboratory responsible for data quality assurance (Designer Genes Technology) using the "BIA/DGT Brasil" software.

Food additives

The Cultron® product, from the company Aleris Nutrition, is characterized as a yeast culture (*Saccharomyces cerevisiae*)

obtained from fermentation in a controlled nutrient medium, containing sugar cane molasses and sequentially corn derivatives.

This technological process maximizes the metabolic activity of the yeast and increases the biological value of the final product. Consequently, it offers greater energy content to the animal, mainly due to the presence of substrates for ruminal bacteria that degrade fibers (its full composition includes: 92% DM, 45% CP, 5% ether extract, 7% FB, 4% MM, 0.05% Ca, 0.78% P, 0.38% K, 15 to 17% β-glucans, 8 to 10% mannan oligosaccharides, in addition to fermentation metabolites with different amino acids, vitamins, enzymes and organic acids).

The sodium monensin-based product used was Rumensin 200® produced by Elanco Saúde Animal (200 g kg-1 of sodium monensin), registered with MAPA under number SP-59410 30002, and classified as an animal performance enhancer.

Facilities and animal consumption

Food was provided twice a day, at 06h00 and 17h30, as a total mixed ration (TMR). The diets consisted (table 1) of 35% corn silage and 65% concentrate on a dry matter basis. The following feeds were used to produce the concentrate: soybean meal, soybean hulls, barley radicles, ground corn grains, ground barley grains, corn germ, calcitic limestone, dicalcium phosphate, common salt, livestock urea, and vitamin-mineral premix.

Table 1
Chemical composition of the foods used to feed the animals and mean values of the experimental diet, on a total dry matter basis

Parameter	Corn silage	Concentrate	Experimental diet
Dry matter, % NM	25.08	84.85	63.93
Mineral matter, % DM	4.69	5.07	4.94
Crude protein, % DM	6.62	14.42	11.69
Ether extract, % DM	4.02	4.97	4.64
Neutral detergent fiber, % DM	50.41	28.38	36.09
Acid detergent fiber, % DM	28.17	13.97	18.94
Lignin, % DM	3.83	1.50	2.32
Total digestible nutrients, % DM	68.12	78.06	74.58
Ca, % DM	0.13	1.67	1.13
P, % DM	0.25	0.58	0.46

[1] Premix guarantee level per kg of concentrate: vit. A: 16,000 IU; vit. D3: 2,000 IU; vit. E: 25 IU; S: 0.36 g; Mg: 0.74 g; Na: 3.6 g; Co: 0.52 mg; Cu: 22.01 mg; F: 18.00 mg; I: 1.07 mg; Mn: 72.80 mg; Se: 0.64 mg; and Zn: 95.20.

Voluntary feed intake was recorded daily by weighing the amount offered and the leftovers from the previous day, considering the daily adjustment of consumption to maintain the leftovers at 3% of dry matter (DM). The additives were diluted and homogenized in 50 g of ground concentrate and spread on the diet at the time of each meal.

In addition to weighing the leftovers for subsequent adjustment of the animals' consumption, the qualitative score of the trough leftovers was evaluated daily, ranging from 1 to 6. The respective scores were graded as follows: 1 (45% silage and 55% concentrate); 2 (40% silage and 60% concentrate); 3 (35% silage and 65% concentrate); 4 (30% silage and 70% concentrate); 5 (25% silage and 75% concentrate); and 6 (20% silage and 80% concentrate), on a dry matter basis, with a score of 3 considered ideal.

Chemical analysis

The corn silage and concentrate samples were placed in a forced-air oven at 55°C for 72 hours to determine the partially dry matter. The pre-dried samples were ground in a Wiley mill with a 1 mm diameter sieve and sent for chemical analysis.

The dry matter (DM), mineral matter (MM), ether extract (EE), and crude protein (CP) contents of the pre-dried feed samples were determined according to AOAC (1995). The neutral detergent fiber (NDF) contents were obtained according to Van Soest et al. (1991) using thermostable α-amylase, and the acid detergent fiber (ADF) and lignin (LIG) contents were estimated following Goering and Van Soest (1970).

The concentration of total digestible nutrients (TDN) was calculated according to equations proposed by Weiss et al. (1992). To determine total dry matter, the samples were placed in an oven at 105ºC for 16 hours (D. J. Silva & Queiroz, 2009) and to determine P and Ca contents, analyses were carried out according to the methodology described by Tedesco et al. (1995).

Animal performance

Animal performance assessments were carried out during the adaptation period and in four consecutive periods of 28 days each. These evaluations were conducted after fasting for solid food for ten hours, to individually weigh the animals. The variables evaluated were body weight (BW), average dry matter intake, expressed in kg animal day^{-1} (DMI), average dry matter intake, expressed as a percentage of body weight (DMI, BW%), average daily weight gain (ADG, kg day^{-1}), and feed conversion (FC, kg kg^{-1}).

DMI was measured through the difference between the daily amount of food provided and the amount of leftover food from the previous day. CMSP was obtained by the ratio of DMI to the average BW for the period, multiplied by 100 (CMSP = DMI ÷BW*100). The ADG was calculated by the difference between the final (BWf) and initial (BWi) BW of the experimental period divided by the days evaluated in each period (ADG= BWf - BWi ÷28). FC was obtained by the ratio of DMI to ADG (FC= DMI ÷ADG).

The experiment lasted 140 days to finish the animals in the feedlot, with 28 days

of adaptation to the diets and experimental facilities and, sequentially, four evaluation periods, each lasting 28 days.

Ingestive behavior

The animals' ingestive behavior was analyzed in two moments in a continuous period of 48 hours, at the end of the first to the second (1st moment) and at the end of the third to the fourth feedlot period (2nd moment), beginning at noon on the first day, and ending at noon on the third day of evaluation (at each moment).

Observations were made by nine observers per shift for 48 hours, taking turns every 6 hours, with readings taken at regular intervals of 3 minutes. Data on ingestive behavior, represented by activities of idling, ruminating, drinking, and feeding, were expressed in hours day^{-1}. Furthermore, following the same methodology, the frequency of occurrence of feeding, drinking, urinating, and defecating activities were determined, expressed in number of times per day. During night observation, the environment was maintained under artificial lighting.

Digestive behavior, based on the determination of the apparent digestibility of DM and NDF, was also examined at the end of the first and third evaluation periods of finishing animals in the feedlot. For this, composite samples of the diets of each treatment were made during the experimental period.

Food samples were taken once a day, for two consecutive days, and stored in a freezer. After the end of the evaluation, samples were thawed, homogenized to form a composite sample, per pen and treatment, and stored at -15ºC.

The average food intake and leftovers were measured daily for two consecutive days (48 hours), together with the total collection of feces produced by the animals in each pen. During the apparent digestibility test, a homogeneous sample of the feces produced was collected from the floor and stored under refrigeration at intervals of six hours. After two consecutive days of collection, these were mixed and homogenized to form a composite sample for laboratory analysis. The weight of the feces sample from each six-hour interval was proportional to the total volume of feces produced.

Diet and fecal samples were dried in a forced air oven at 55°C to constant weight, and corrected for total dry matter at 105°C. The DM of leftovers and feces from each experimental unit was determined using the same procedures adopted for diet analysis.

The apparent digestibility coefficient (DC) of DM and NDF of the experimental diets was estimated according to the following formula: DC (%) = [(g of nutrient ingested – g of nutrient excreted) ÷ g of nutrient ingested] x 100.

The fecal score was determined daily for each pen according to a methodology adapted from Looper et al. (2001) and Ferreira et al. (2013) ranging from 1 to 5: 1 (watery feces, without consistency); 2 (loose feces, with few ripples, without definition of shape); 3 (pasty feces with piles between 1 and 4.5 cm high and with 2-4 concentric rings); 4 (slightly liquid feces with piles between 5 and 7.5 cm high); and 5 (hardened feces with piles more than 7.5 cm high), with score 3 considered ideal.

Carcass ultrasound examination

At the beginning of the experimental period and upon shipping the animals for slaughter, evaluations of rib eye area (REA), marbling, ratio (height-to-width ratio of REA), subcutaneous fat thickness of the *Longuissimus dorsi* muscle, and rump fat thickness were carried out using a set of equipment consisting of an echo camera (Aloka® SSD-500 Vet) coupled to a 17 cm probe at 3.5 MHz.

Measurements were taken in the region of the 12th and 13th ribs, over the *Longuissimus dorsi* muscle. From the REA measurements, the ratio was calculated, which represents the relationship between its height and width. The images were interpreted by the laboratory responsible for ensuring data quality (Designer Genes Technology) using the "BIA/DGT Brasil" software.

Marbling was assessed through the existence of fat deposits between muscle fibers in *Longuissimus dorsi* and scored using increasing indices from 1 (non-existent) to 5 (excessive) adapted from the system proposed by Müller (1987).

At the end of the feedlot period, animals were fasted for solids for ten hours before shipment to the slaughterhouse and were weighed to obtain the farm weight. The carcass gain during the feedlot period (GCC), expressed in kg, was obtained by the difference between the hot carcass weight at slaughter and the initial body weight (BWi) of the animals under a theoretical carcass yield of 50%.

Taking the period of 112 days of feedlot as a basis, the average carcass gain (GMC) was also estimated, expressed in kg day^{-1}, obtained by the ratio of GCC to BW, as well as the efficiency in converting ingested DM into carcass (ETC), expressed in kg DM kg $carcass^{-1}$ and the efficiency in converting weight gain into carcass, which was obtained by the ratio of GMC to ADG (GMC ÷ ADG), expressed in %. These calculations considered the hot carcass weight.

Assessments at the slaughterhouse

Four development measurements were taken on the carcasses: carcass length, which is the distance between the medial cranial edge of the pubic bone and the medial cranial edge of the first rib; arm length, which is the distance between the olecranon tuberosity and the radiocarpal joint; arm circumference, obtained in the median region of the arm by encircling it with a measuring tape; and the round thickness, measured using a compass, perpendicular to the carcass length, taking the largest distance between the cut that separates the two half carcasses and the lateral muscles of the thigh, as suggested by Müller (1987). The thickness of subcutaneous fat over the Longissimus dorsi muscle between the 12th and 13th ribs, as well as in the forequarter, ribs, and hindquarter, was also measured using a digital caliper.

The characterization of body parts that were not part of the carcass of the slaughtered steers was also made by collecting the weights of the following non-carcass components: head, tongue, tail, testicles, hide, and feet (called external components); and heart, kidneys, liver, lungs, empty rumen-reticle, full rumen-reticle, empty abomasum (called vital organs).

Statistical analysis

For parameters related to animal performance, ingestive behavior, carcass traits, and apparent digestibility, the experimental design was completely randomized consisting of three treatments, with six replications. Each replication corresponded to a pen with two animals. Data collected for each variable were tested by analysis of variance followed by the comparison of means at 5% significance, using the SAS statistical software (Statistical Analysis System [SAS], 1993).

The analysis of each variable followed the statistical model: $Y_{ijk} = \mu + A_i + E_{ij}$; Where: Y_{ijkl} = dependent variables; μ = Overall mean of all observations; A_i = Effect of the type of additive of order "i", where 1 = diet with sodium monensin, 2 = diet with yeast culture, and 3 = diet with sodium monensin + yeast culture; and E_{ijk} = Residual random effect.

Results and Discussion

According to the animal performance and DM intake data in Table 2, in general, at the end of 112 days of finishing, animals supplemented with yeast culture had greater ($P<0.05$) average daily weight gain (1.612 kg day^{-1}) compared to those supplemented with monensin alone or in combination with yeast culture (1.454 and 1.503 kg day^{-1}, respectively).

Data on improvement in average daily weight gain in feedlot animals on yeast culture are reported by Melo et al. (2023) and Oliveira et al. (2023), using the same dose of 7g animal day^{-1}, with mean values of 1.668 kg and 1.661 kg, respectively. In a meta-analysis on yeast culture, Wagner et al. (2016) found an increase in ADG of 6.5% compared to animals not supplemented with culture.

This effect can be partially explained by the ability of yeast culture to alter ruminal fermentation, stimulating the growth and activity of bacteria that digest fiber and utilize lactate (Zhu et al., 2017), as well as by the presence of functional metabolites (organic acids, vitamin B, amino acids, and enzymes). Likewise, by increasing the availability of nutrients to the ruminal microbiota through metabolites, there is greater activity of ruminal microorganisms, which could explain the positive effects of DMI.

Previous studies by Swyers et al. (2014) in feedlots as the present study did not show the synergy between yeast culture (28 g/day) and sodium monensin (33 mg/kg DM) in the diet for weight gain, in which the ADG was lower with the combination (1.57 and 1.62 kg, respectively) compared only with a diet based on monensin.

Regarding DM intake, whether expressed in kg day-1 or % body weight, these were higher in animals supplemented with yeast culture compared to sodium monensin. In turn, the combination of additives presented intermediate values. For feed conversion and trough and fecal scores, there was no difference between the treatments tested.

The results regarding ADG, CMSD and CMSP may be associated with the mode of action of the yeast culture, which maintains a more stable ruminal pH and is conducive to the growth of cellulolytic bacteria (*Fibrobacter succinogenes* and *Ruminococcus flavefaciens*) and lactate-using bacteria (*Megasphaera elsdenii* and

Selenomonas ruminantium), which improve DMD and NDFD, and consequently CMSD (Dias et al., 2018; Zhu et al., 2017). This higher DMI is also due to the improvement in the digestion of organic matter, which enhances feed efficiency, as it presents a higher average daily gain (Desnoyers et al., 2009).

However, the lower DMI in animals fed monensin is due to its action, which generally depresses DMI (Nagaraja et al., 1997), as highlighted in a meta-analysis by Duffield et al. (2012) that reports a 3% decrease in DMI. It is suggested that monensin increases the synthesis of propionate, which is involved in the regulation of intake in the central nervous system, and due to changes in the ruminal microbiota that increase the proportion of propionate and alter the satiety mechanisms, reducing the amount of food ingested, and the physiological effect of the energy level regulates intake and increases energy efficiency, which favors the reduction of consumption (González et al., 2012).

Table 2
Average daily weight gain (ADG), dry matter intake expressed in kg day^{-1} (DMID) or per 100 kg of body weight (DMIB), feed conversion (FC), and qualitative score of trough and feces, of feedlot-finished steers on yeast culture combined or not with sodium monensin in the diet

Experimental diet						
Parameter	Sodium Monensin	Yeast Culture	Combination	Mean	SEM	Prob.
GMD, kg day^{-1}:						
Adaptation	1.560	1.577	1.518	1.552	0.145	0.9787
0 to 28 days	1.488 b	1.601 a	1.470 b	1.520	0.062	0.1255
0 to 56 days	1.479 b	1.686 a	1.510 b	1.559	0.041	0.0504
0 to 84 days	1.421 b	1.596 a	1.446 b	1.488	0.090	0.0570
0 to 112 days	1.454 b	1.612 a	1.503 b	1.523	0.023	0.0265
CMSD, kg day^{-1}:						
Adaptation	10.43	10.77	10.57	10.59	0.208	0.5248
0 to 28 days	10.14	10.73	10.20	10.36	0.244	0.2029
0 to 56 days	10.08 b	10.96 a	10.23 b	10.42	0.252	0.0531
0 to 84 days	9.93 b	10.87 a	10.14 ab	10.31	0.261	0.0547
0 to 112 days	9.74 b	10.81 a	10.06 ab	10.21	0.282	0.0465
CMSP, % body weight:						
Adaptation	2.55	2.62	2.65	2.62	0.053	0.3326
0 to 28 days	2.30	2.44	2.37	2.37	0.048	0.1718
0 to 56 days	2.20 b	2.34 a	2.27 b	2.27	0.039	0.0325
0 to 84 days	2.10 b	2.24 a	2.17 ab	2.17	0.035	0.0386
0 to 112 days	2.01 b	2.15 a	2.08 ab	2.08	0.033	0.0273

continue...

continuation...

FC: CMSD:GMD, kg kg^{-1}:						
Adaptation	7.96	7.94	7.24	7.72	0.776	0.9568
0 to 28 days	6.97	6.93	7.13	7.01	0.482	0.9568
0 to 56 days	6.91	6.83	7.06	6.93	0.413	0.9276
0 to 84 days	6.88	6.81	7.05	6.91	0.377	0.9025
0 to 112 days	6.75	6.77	6.94	6.82	0.334	0.9063
Trough score, score:						
Adaptation	3.06	3.00	2.82	2.96	0.198	0.6785
0 to 28 days	2.97	2.93	2.56	2.82	0.183	0.2373
0 to 56 days	2.81	2.82	2.49	2.71	0.153	0.2469
0 to 84 days	2.71	2.70	2.42	2.61	0.128	0.2347
0 to 112 days	2.67	2.64	2.41	2.58	0.123	0.2903
Fecal score, score:						
Adaptation	3.19	3.23	3.15	3.19	0.091	0.8648
0 to 28 days	3.09	3.04	3.04	3.06	0.048	0.7318
0 to 56 days	3.07	3.06	3.04	3.06	0.041	0.8384
0 to 84 days	3.03	3.04	3.01	3.02	0.033	0.8654
0 to 112 days	3.04	3.03	3.02	3.03	0.035	0.9279

Means in the same row, followed by different lowercase letters, are significantly different by Tukey's test at 5%.
CV: Coefficient of variation; SEM: Standard error of the mean.

In Table 3, animals on the yeast culture diet had higher ($P<0.05$) average daily carcass gains (1.159 versus 1.070 kg day^{-1}) and consequently higher carcass gains in the total feedlot period (129.9 versus 119.8 kg) compared to the diet with sodium monensin. These results are due to the higher DMI, ADG, NDFD, and DMD of the animals receiving yeast culture.

Table 3
Average carcass gain, expressed in kg day^{-1} (GMC) and kg equivalent to the total feedlot period (GCC), efficiency in converting weight gain into carcass (GMC GMD-1, %), efficiency in converting dry matter consumed into carcass (ETC), and digestive behavior, represented by fecal production in kg day^{-1}, natural basis (PFMN) or dry basis (PFMS), fecal dry matter content (MSF) and fecal neutral detergent fiber (NDF) content, apparent digestibility of DM (DMD) and NDF (NDFF) of the diet of feedlot-finished steers on yeast culture combined or not with sodium monensin in the diet

Experimental diet						
Parameter	Sodium Monensin	Yeast Culture	Combination	Mean	SEM	Prob.
GMC	1.070 [b]	1.159 [a]	1.090 [b]	1.106	0.049	0.0347
GCC	119.8 [b]	129.9 [a]	122.1 [b]	123.9	5.255	0.0320
GMC GMD	75.28	72.42	74.17	73.96	2.028	0.1677
ETC	9.15	9.34	9.30	9.27	0.268	0.8738
PFMN	15.00	16.10	15.46	15.52	0.623	0.4700
PFMS	2.74	2.88	2.79	2.80	0.099	0.5997
MSF	18.21	17.82	18.03	18.01	0.236	0.5186
FDNF	36.70	35.45	36.61	36.25	0.467	0.1425
DMS	71.13 [ab]	72.37 [a]	70.72 [b]	71.40	0.743	0.0258
DFDN	44.03 [b]	48.28 [a]	43.46 [b]	45.25	1.664	0.0159

Means in the same row, followed by different lowercase letters, are significantly different by Tukey's test at 5%.
CV: Coefficient of variation; SEM: Standard error of the mean.

For the efficiency in converting dry matter consumed into carcass and efficiency in converting weight gain into carcass, there was no statistical difference (P>0.05) for the treatments evaluated. For the digestive behavior, the production of feces (kg day-1) both in dry matter and in natural matter, and the dry matter and neutral detergent fiber contents of the feces were not altered (P>0.05) with the inclusion of different types of additives, alone or combined.

The apparent supplementation digestibility of dry matter, with the supplementation of yeast culture, was improved (P<0.05) compared to the diet combined or not with sodium monensin, However, for the digestibility of neutral detergent fiber, the yeast culture was superior to the others and sodium monensin was intermediate.

Melo et al. (2023) obtained the same result as the present study, testing the same dose, regarding the apparent digestibility of dry matter. This was also emphasized by Halfen et al. (2021) who worked with lactating cows supplemented with yeast culture (14 g animal day-1) with a diet around 60% roughage and observed a greater amount of cellulolytic bacteria than aminolytic bacteria in the rumen, being beneficial for the ruminal environment and animal performance.

Yeast culture supplementation provides organic acids, B vitamins, and amino acids. These substrates are used by Selenomonas ruminantium, which consumes lactic acid produced from the degradation of the diet. This stabilizes ruminal pH and bacterial flora and maintains a ruminal environment favorable to the development of fibrolytic bacteria (Vyas et al., 2014; Shen et al., 2019).

Regarding the results of monensin on digestibility, Nagaraja et al. (1997) argue that the inclusion of monensin inhibits fiber digestibility in beef cattle, which explains the lower NDF utilization in animals supplemented only with monensin.

The response of monensin to DMD and NDFD is related to some factors such as DM retention time, lower voluntary feed intake, and ruminal conditions. Monensin is expected to inhibit some cellulolytic bacteria (Ruminococcus albus, Ruminococcus flavefaciens, and Butyrivibrio fibrisolvens) (Chen & Wolin, 1979), which would justify the lower value of DMD. However, it is not known exactly how many and what bacteria are, hence the intermediate NDFD value (Domescik & Martin, 1999).

The ingestive behavior data in Table 4 show that the times dedicated to eating, drinking, idling, and ruminating activities were not altered (P>0.05) with the supplementation of different types of additives.

Table 4
Ingestive behavior represented in hours day-1 or in the frequency of activities performed (times day^{-1}) of feedlot-finished steers on yeast culture combined or not with sodium monensin in the diet

Experimental diet						
Parameter	Sodium Monensin	Yeast Culture	Combination	Mean	SEM	Prob.
Hours day^{-1}						
Feeding	2.26	2.42	2.61	2.43	0.126	0.0853
Watering	0.23	0.26	0.25	0.25	0.033	0.6554
Ruminating	4.90	5.19	5.50	5.20	0.421	0.5611
Idling	16.69	16.16	15.68	16.18	0.440	0.2028
Times day^{-1}						
Feeding	19.0	18.5	20.1	19.2	1.666	0.7562
Watering	7.5	7.5	9.3	8.1	0.853	0.7240
Defecating	8.8	8.8	7.9	8.9	0.757	0.8315
Urinating	6.9	6.7	7.5	7.0	0.594	0.5221

Means in the same row, followed by different lowercase letters, are significantly different by Tukey's test at 5%.
CV: Coefficient of variation; SEM: Standard error of the mean.

When evaluating ingestive behavior, expressed in the frequency of activities in times day^{-1} (Table 4), there was no significant difference (P>0.05) between the experimental treatments for the parameters evaluated. Melo et al. (2023) also detected no behavioral differences when evaluating the use of yeast culture in the diet.

Table 5 lists the quantitative carcass data, showing a significant difference (P<0.05) for slaughter weight and hot carcass weight, with higher weights in animals supplemented with yeast culture (598.8 kg and 339.0 kg, respectively) compared to those on diets combined or not with sodium monensin. Oliveira et al. (2023) report that this may be indicative of better use of the diet, which obtained the same results, working with the same dose of yeast culture.

The inclusion of yeast culture in the diet also promoted a better degree of carcass finishing, with higher values (P<0.05) in fat thickness in the forequarter (3.92 mm) and hindquarter (7.17 mm) compared to the diet with sodium monensin, without differing from the diet with the combination of the additives. Oliveira et al. (2023) also found improvements in these parameters working with the same dose.

The change in the ruminal fermentation pattern in response to diet and the use of feed additives may affect the production of SCFA and, consequently, the acetate: propionate ratio. Acetate is the major precursor for lipogenesis and is generally produced in a greater proportion by cellulolytic bacteria, and propionate by starch-fermenting bacteria (Resende et al., 2006). This action metabolism probably contributed to the higher values in animals supplemented with yeast culture for fat thickness in the fore- and hindquarters.

Table 5
Carcass traits of feedlot-finished steers on yeast culture combined or not with sodium monensin in the diet

Experimental diet						
Parameter	Sodium Monensin	Yeast Culture	Combination	Mean	SEM	Prob.
Initial body weight (kg)	419.9	418.2	409.4	415.9	5.162	0.3307
Body weight at slaughter (kg)	582.8 [b]	598.8 [a]	577.7 [b]	586.4	11.826	0.0459
Hot carcass weight (kg)	329.9 [b]	339.0 [a]	326.8 [b]	331.8	6.624	0.0202
Carcass yield (%)	56.60	56.63	56.59	56.61	0.356	0.9971
Longissimus dorsi	5.03	5.47	4.89	5.13	0.272	0.2558
Forequarter	3.58 [ab]	3.92 [a]	2.92 [b]	3.47	0.237	0.0385
Ribs	5.00	5.33	5.08	5.14	0.283	0.6961
Hindquarter	6.50 [b]	7.17 [a]	6.67 [ab]	6.78	0.501	0.0325
Carcass length	139.25	138.00	137.08	138.11	1.229	0.4751
Round thickness	28.83	28.92	29.42	29.06	0.508	0.6868
Arm length	45.42	46.17	45.67	45.75	1.356	0.9243
Arm circumference	51.50	49.92	49.92	50.44	0.972	0.4329
Heart	0.34	0.30	0.28	0.31	0.024	0.2539
Liver	1.02	1.07	1.05	1.04	0.053	0.7862
Lungs	1.06	1.05	1.07	1.06	0.023	0.7241
Kidneys	0.21	0.17	0.18	0.19	0.023	0.6206
Full abomasum	0.80	0.90	0.99	0.90	0.092	0.3716
Full rumen	4.79	5.40	6.60	5.60	0.362	0.0995
Empty rumen	1.56	1.68	1.78	1.68	0.038	0.0837
Testicles	0.33	0.33	0.31	0.32	0.019	0.5544
Tail	0.28	0.27	0.28	0.28	0.019	0.9313
Tongue	0.15	0.15	0.17	0.16	0.011	0.6576
Head	2.48	2.46	2.47	2.47	0.056	0.9569
Feet	1.49	1.45	1.50	1.48	0.031	0.4105
Hide	7.75	7.50	7.74	7.66	0.298	0.8034

Means in the same row, followed by different lowercase letters, are significantly different by Tukey's test at 5%.
CV: Coefficient of variation; SEM: Standard error of the mean.

In the overall average, for the parameters carcass yield, carcass length, round thickness, arm length, and arm circumference, there was no significant difference (P>0.05) between treatments, showing mean values of (56.61%, 138.11 cm, 29.06 cm, 45.75 cm, and 50.44 cm), respectively. In the evaluation of the weights of vital organs, expressed as % body weight, there was also no significant difference (P>0.05) between the treatments evaluated.

Several experiments also demonstrated no effect of yeast culture supplementation on carcass traits in goats (Whitley et al., 2009), lambs (Kawas et al., 2007), and steers (Mir & Mir, 1994). Nevertheless, for Pazdiora et al. (2009), this lack of difference is because these traits have a great genetic influence and little relation to the diet or additive used since the animals in the present study have similar breed and genetic patterns.

In table 6, for values at slaughter and feedlot gain, the carcasses of animals supplemented with yeast culture presented higher (P<0.05) AOL and rump fat thickness compared to those on a diet with sodium monensin. For the ratio, marbling, and subcutaneous fat thickness, there was no significant difference between the treatments tested. The association was intermediate only for rump fat thickness.

Table 6
Values at slaughter and gain during the feedlot period of loin eye area (AOL), ratio, marbling, subcutaneous fat thickness (EGS), and rump fat thickness (EGP), of feedlot-finished steers on yeast culture combined or not with sodium monensin in the diet

Experimental diet						
Parameter	Sodium Monensin	Yeast Culture	Combination	Mean	SEM	Prob.
AOL	92.42 [b]	96.89 [a]	92.53 [b]	93.95	2.075	0.0416
Ratio	0.56	0.56	0.55	0.56	0.011	0.6576
Marbling	3.43	3.47	3.60	3.50	0.120	0.6593
EGS	7.54	8.07	7.40	7.67	0.428	0.5051
EGP	8.76 [b]	10.19 [a]	9.40 [ab]	9.45	0.587	0.0274
AOL	28.28 [b]	31.21 [a]	27.64 [b]	29.04	1.080	0.0399
Ratio	0.10	0.09	0.10	0.10	0.007	0.7625
Marbling	0.91	1.23	1.16	1.10	0.078	0.1924
EGS	4.71	5.11	4.64	4.82	0.416	0.6890
EGP	4.58 [b]	5.79 [a]	5.24 [ab]	5.20	0.440	0.0243

Means in the same row, followed by different lowercase letters, are significantly different by Tukey's test at 5%.
CV: Coefficient of variation; SEM: Standard error of the mean.

Both yeast culture and sodium monensin favor the reduction in the concentration of lactic acid in the rumen, with yeast culture stimulating lactic acid-utilizing bacteria and sodium monensin depressing lactic acid-producing bacteria, which have been associated with increased animal efficiency due to their involvement in channeling the metabolic pathway that converts lactate into propionate, which is the main precursor for gluconeogenesis, which may explain why yeast culture was superior and monensin was intermediate for AOL (Shabat et al., 2016).

In addition, it has been suggested that yeast culture promotes the development of ruminal protozoa that can engulf starch particles and limit the access of lactic acid-producing bacteria to starch (Oliveira et al., 2023).

For rump fat thickness, as the yeast culture tends to favor cellulolytic bacteria, where there is greater production of acetate, which is the main precursor for lipogenesis, and when they are in positive energy balance, they promote better carcass finishing through fat deposition, resulting in higher rump fat thickness (Resende et al., 2006; Fernandes et al., 2022; Gonçalves et al., 2012).

Conclusion

The use of yeast culture promoted greater daily body weight gain and daily carcass gain due to improvements in the apparent digestibility of the diet, which promoted better carcass finishing compared to sodium monensin.

The combination of yeast culture and sodium monensin presented intermediate values compared to the treatment with yeast culture and monensin individually, for rump fat thickness (5.24 mm) and hindquarter fat thickness (6.67 mm).

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