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Associative effect of essential oils, tannins, and sodium monensin on the performance of steers finished in feedlot

Efeito associativo de óleos essenciais, taninos e monensina sódica sobre o desempenho de novilhos terminados em confinamento

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Highlights

Essential oils and tannins efficiently replaced monensin in the diet.
Diet digestibility was improved with the use of essential oils and tannins.
Essential oils and tannins and sodium monensin ensured higher carcass yield.

Abstract

The objective was to evaluate the productive performance, ingestive behavior, apparent digestibility of the diet and carcass traits of beef steers finished in feedlot under the effect of including tannins and essential oils (TAN+EO) alone or combined with sodium monensin (MO) in the feed. For this purpose, 30 ½ blood Angus steers from the same herd, with an average age of 12 months and an average initial body weight of 367.8 kg were used. The experimental design was randomized blocks, consisting of three treatments: MO - diet with sodium monensin (25 mg kg DM^{-1}); TAN+EO - diet with tannins and essential oils (1.5 g kg DM^{-1}); and MO+TAN+EO - diet with sodium monensin + tannins and essential oils (25 mg kg DM^{-1} + 1.5 g kg DM^{-1}), with five repetitions, where each repetition was represented by a stall with two animals. Diets were formulated

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and consisted of a mixture of 40% corn silage and 60% concentrate, which was fed to the animals twice a day, at 06h00 am and 05h30 pm. There was no difference (P>0.05) in average daily weight gain of animals between treatments, with an average of 1.392 kg day^{-1}. Carcass yield was higher for animals that received the compound of essential oils and tannins (55.72%), compared to animals fed the combination of tannins, essential oils and monensin (54.54%) but did not differ from those supplemented with sodium monensin alone (55.58%). Supplementation with essential oils and tannins improved the apparent digestibility of the diet, however, did not promote changes in the ingestive behavior and carcass traits of steers. The combination of essential oils and tannins with sodium monensin did not show a potentiated effect on animal performance, digestibility of DM, digestive and ingestive behavior and carcass traits of feedlot finished steers compared to the combined use of essential oils with tannins.
Key words: Food additive. Ionophores. Plant extract. Ruminal fermentation.

Resumo

Objetivou-se avaliar o desempenho produtivo, o comportamento ingestivo, a digestibilidade aparente da dieta e as características de carcaça de novilhos de corte terminados em confinamento sob efeito da inclusão de taninos e óleos essenciais (TAN+OE) de forma isolada ou associada a monensina sódica (MO) na ração. Para tal utilizou-se 30 novilhos, ½ sangue Angus, provenientes de mesmo rebanho, com idade média de 12 meses e peso vivo médio inicial de 367,8 kg. O delineamento experimental foi o de blocos casualizados, constituído de três tratamentos sendo: MO - dieta com monensina sódica (25 mg kg MS^{-1}); TAN+OE - dieta com taninos e óleos essenciais (1,5 g kg MS^{-1}); e MO+TAN+OE - dieta com monensina sódica + taninos e óleos essenciais (25 mg kg MS^{-1} + 1,5 g kg MS^{-1}), com cinco repetições, onde cada repetição foi representada por uma baia com dois animais. As dietas foram formuladas e constituídas por uma mistura de 40% de silagem de milho e 60% de concentrado, a qual foi fornecida aos animais duas vezes ao dia, às 06h00 e às 17h30 horas. Não ocorreu diferença (P>0,05) no ganho de peso médio diário dos animais entre os tratamentos, apresentando média de 1,392 kg dia^{-1}. O rendimento de carcaça foi superior para os animais que receberam composto de óleos essenciais e taninos (55,72%), em relação aos animais que receberam a associação de taninos, óleos essências e monensina (54,54%) no entanto não diferiram dos suplementados com monensina sódica isolada (55,58%). A suplementação com óleos essenciais e taninos melhorou a digestibilidade aparente da dieta, entretanto, não promoveu alterações no comportamento ingestivo e nas características de carcaça de novilhos. A associação de óleos essenciais e taninos à monensina sódica não apresentou efeito potencializado no desempenho animal, digestibilidade da MS, comportamento digestivo e ingestivo e características de carcaça de novilhos terminados em confinamento frente ao uso de óleos essenciais com taninos.
Palavras-chave: Aditivo alimentar. Extrato de plantas. Fermentação ruminal. Ionóforos.

Introduction

Some additives used in ruminant nutrition aim to manipulate fermentation patterns and modify the ruminal microbial composition, aiming at the intensification of productive gains by promoting the maximization of dietary digestion and the synthesis of products, such as short-chain fatty acids, reducing energy losses, improving feed conversion efficiency and animal growth rate (Oliveira et al., 2019; Min et al., 2020).

Among the additives with these characteristics, tannins and essential oils are naturally derived from plants, and monensin sodium is an ionophore. However, its use has been questioned and has been banned by the European Union due to the possibility of leaving residues in the meat (Stella et al., 2017) and since then, the search for natural products that play a similar role and can potentially replace ionophores is increasingly being performed (Shurson, 2018; Calo et al., 2015).

Tannins are polyphenolic compounds found in many plant species, and subdivided into condensed and hydrolysable. Condensed tannins have their flavan-3-ol subunits linked together, forming oligomers and polymers, whereas hydrolysable tannins are esters of gallic or ellagic acid linked to a polyol core (Naumann et al., 2017). They have antimicrobial, antiparasitic, antioxidant, anti-inflammatory, immunomodulatory action, reduce enteric methane production, N excretion via urine, and increase duodenal flow of microbial protein and amino acids (Orlandi et al., 2015; Naumann et al., 2017; Huang et al., 2018; Seoni et al., 2021).

Evaluating the performance of confined heifers supplemented with sodium monensin or tannins Pordomingo et al. (2006) observed higher daily intake for animals supplemented with tannin compared to those supplemented with monensin. Rivera-Méndez (2016) observed increase in the dry matter intake of animals receiving tannins as a supplement in the diet. Mezzomo et al. (2016) supplementing finishing cattle with tannins observed greater transformation of ingested food into muscles

Essential oils, also derived from plants, are volatile substances, which can be used as feed flavoring and/or preservatives (Khorshidian et al., 2018), and modulators of ruminal microbial flora (Mullen et al., 2014; Rossi et al., 2015). This is the main action of essential oils in animal nutrition, because by modulating the ruminal microbiota, they reduce deamination and ammonia production, providing greater nitrogen flow to the intestine (Patra, 2011; Jafari et al., 2019).

When using a blend of essential oils Meschiatti et al. (2019) found an increase in dry matter consumption by animals. On the other hand, the same trend was not observed by Heker et al. (2018) when studying the effect of a blend of essential oils, but at slaughter, they observed a greater deposition of subcutaneous fat in the animals of this treatment

Sodium monensin is a metabolite from the bacterium *Streptomyces cinnamonensis,* and is classified as an ionophore (Soares et al., 2015). This in turn can improve the feed efficiency of animals, due to its ability to change the rumen microbiota, the fermentation pattern of foods, promote stability in rumen pH and, in diets with higher energy value, it can increase the concentrations of propionic acid, which is a precursor of glucose (Drong et al., 2016).

Considering the mechanisms of action of tannins and essential oils, it is suggested that both can complement each other, however, studies evaluating the effect of their combination on the productive performance of confined cattle are scarce, and because the Brazilian Ministry of Agriculture, Livestock and Supply did not ban the use of monensin sodium, the combination of both additives may have a synergistic effect and thus maximize animal production, however, studies on this magnitude also need to be carried out and thus respond to these hypotheses.

In this context, the objective of this study was to evaluate the productive performance, animal behavior, apparent digestibility of the diet and carcass traits of beef steers finished in feedlot supplemented with essential oils combined with tannins alone or with sodium monensin.

Material and Methods

Location, experimental material and facilities

The experiment was carried out at the Animal Production Center (NUPRAN) together with Master's Program in Veterinary Sciences of the Agricultural and Environmental Sciences Sector of the State University of the Midwest (UNICENTRO), located in Guarapuava, state of Paraná. All experimental procedures were previously submitted to the Ethics Committee for Animal Experimentation (CEUA/UNICENTRO) and approved under protocol 026/2017.

As experimental material, 30 whole ½ blood Angus steers, with an average initial weight of 367.8 kg and an initial average age of 12 months, previously dewormed, were used. The experimental design was randomized blocks, consisting of three treatments: MO - diet with sodium monensin (25 mg kg DM day^{-1}); TAN+EO - diet with tannins and essential oils (1.5 g kg DM day^{-1}); and MO+TAN+EO - diet with sodium monensin + tannins and essential oils (25 mg kg DM day^{-1} + 1.5 g kg DM day^{-1}), with five repetitions each, where each repetition corresponded to a stall with two animals.

The facilities consisted of 15 half-roofed feedlot stalls, with an area of 15 m^2 each (2.5 m x 6.0 m). Each stall has a concrete feeder measuring 2.30 m in length, 0.60 m in width and 0.35 m in height and a metallic drinker controlled by an automatic float.

Description of feed additives and diet

The product Valopro® is an additive composed of an active mixture of carvacrol and cinnamaldehyde essential oils, acacia and chestnut tree-based tannins, which are hydrolysable tannins and mineral elements. Its active compounds are natural substances found in herbs.

The used sodium monensin-based product was Rumensin® 200 (Elanco Saúde Animal), registered with MAPA under number SP-59410 30002, which is classified as an animal performance enhancer.

Diets were formulated following the National Research Council [NRC] (2000), and consisted of a mixture of 40% corn silage and 60% pelleted concentrate. The pelleted concentrate was prepared with soybean meal, wheat bran, malt radicle, corn, soybean hulls, limestone, dicalcium phosphate, livestock urea, common salt and vitamin and mineral premix. The diet was supplied as total mixed ration and aiming at the complete intake of the additives by the animals, they were homogenized in 50 g ground concentrate (vehicle) and spread over the diet at the time of each meal.

Data collection

The experiment lasted 100 days for finishing animals in feedlot, with 16 days for adaptation to the diets and experimental facilities and, sequentially, three evaluation periods of 28 days. Animals were fed twice a day (06h00 and 17h30).

Voluntary food intake was recorded daily by weighing the amount offered and leftovers from the previous day. The supply was adjusted daily, allowing for 5% leftover of the dry matter offered in relation to the consumed.

Animals were weighed at the beginning and end of each 28-day experimental period, where the animals were previously fasted from solids for 10 hours. The variables evaluated were body weight (BW), average dry matter intake, expressed in kg animal day^{-1} (ADMI), average dry matter intake, expressed as a percentage of body weight (ADMI, BW), average daily weight gain (ADG, kg day^{-1}) and feed efficiency (FE, kg kg^{-1}).

ADMI was measured by the difference between the daily amount of food supplied and the amount of food leftovers from the previous day, corrected for total dry matter. ADMI, BW was obtained by the ratio of ADMI to the average BW of the period ADMI,% BW= $\left(\frac{\text{ADMI}}{\text{BW}}\right)$ *100. ADG was calculated by the difference between the final (BWf) and initial (BWi) BW of the experimental period divided by the days evaluated G ADG $\left(\frac{\text{BWf}-\text{BWi}}{28}\right)$. FE was obtained by the ratio of the ADG to the ADMI: FE= $\left(\frac{\text{ADG}}{\text{ADMI}}\right)$.

The fecal score of each stall was daily evaluated by means of visual observation. Feces were scored from 1 to 5, as follows: 1- watery feces, without consistency; 2 - loose feces, with few undulations, no defined shape; 3 - pasty feces with piles between 1 and 4.5 centimeters in height and with 2 to 4 concentric rings; 4 - low liquid feces with piles between 5 and 7.5 centimeters in height; 5 - hard feces with piles more than 7.5 centimeters in height, according to methodology adapted from Looper et al. (2001) and Ferreira et al. (2013).

At the end of the confinement, animals were fasted from solids for 10 hours for weighing before shipment to the slaughterhouse, obtaining the farm weight. The carcass gain in the feedlot period (CG) expressed in kg, was obtained by the ratio: ACG =HCW-(BWi x 0.50), where ACG = average carcass gain during the feedlot; HCW = hot carcass weight (kg), which was measured in a digital scale on the slaughterhouse and BWi = initial body weight (kg), of animals with a theoretical carcass dressing of 50%. Based on the period of 84 days of feedlot, the average daily carcass gain (ADCG) was expressed in kg day^{-1} and calculated as following: ADCG = $\frac{\text{ACG}}{\text{FP}}$, where ADCG = average daily carcass gain; ACG = average carcass gain (kg) during the feedlot period, and FP = feedlot period (days). The efficiency of transformation of the dry matter intake into carcass (ETDMIC) was also calculated, expressed in kg DM kg carcass^{-1} and the efficiency of transformation of weight gain into carcass (ETWGC), which was obtained by the ratio of ACG and ADG (ACG ÷ ADG), expressed in % calculations performed as proposed by Horst et al. (2019). Values of hot carcass weight were used for the calculations.

Four measures of development were taken in 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 perimeter, obtained in the middle region of the arm, encircling it with a measuring tape; and thigh thickness, measured with a compass, perpendicularly to the length of the carcass, taking the greatest distance between the cut that separates the two half carcasses and the lateral muscles of the thigh, according to the methodologies suggested by Müller (1987). The subcutaneous fat thickness over the Longissimus dorsi muscle between the 12th and 13th ribs was also measured using a digital caliper.

Chemical analysis of food

Samples of corn silage and concentrate were dried in a ventilation oven at 55°C for 72 hours to determine the partially dry matter. Pre-dried samples were ground in a Wiley mill with a 1 mm-sieve and subsequently sent for chemical analysis.

From the pre-dried samples of corn silage and concentrate, the contents of dry matter (DM), mineral matter (MM), ether extract (EE) and crude protein (CP) were determined, according to techniques described in the Association of Official Analytical Chemists [AOAC] (2000). Neutral detergent fiber (NDF) content was obtained according to the method of Van Soest et al. (1991) with thermostable α-amylase, acid detergent fiber (ADF) and lignin (LIG), according to Goering and Van Soest (1970). Total digestible nutrients (TDN) content was calculated according to equations proposed by Weiss et al. (1992). To determine the total dry matter, samples were taken to an oven at 105ºC for 16 hours (D. J. Silva & Queiroz, 2009) and to determine the P and Ca contents, analyses were performed according to the methodology described by Tedesco et al. (1995). Table 1 lists the chemical composition of the feed used in animal feeding and the average values of the experimental feed, on a total dry matter basis.

Ingestive behavior

The ingestive behavior was evaluated twice for 48 hours (1st, starting on day 42 and ending on day 44 of the experiment) and (2nd, starting on day 70 and ending on day 72 of the experiment), starting at 12 noon on the first day and ending at 12 noon on the third day of evaluation (at each evaluation). Observations were performed by six observers per shift, on a rotation system every six hours. Readings were taken at regular 3-minute intervals. Animal behavior data, represented by idling, ruminating, drinking and feeding, were expressed in hours day^{-1}. On the same occasion, following the same methodology, the frequency of non-ingestive oral behavior activities, visits to the feed trough for intake (diet), visits to the drinking fountain to drink water, liquid excretions and solid excretions, expressed in number of times day^{-1}. In the night observation, the environment was kept under artificial lighting, a condition that occurs since the arrival of the animals.

Table 1
Chemical composition of foods used in animal feed and average values of the experimental diet, on a total dry matter basis

Parameters	Corn Silage	Pelletized concentrate[1]	Experimental diet
Dry matter, %	42.21	90.33	71.08
Mineral matter, % DM	2.99	4.56	3.93
Ether extract, % DM	2.96	2.99	2.98
Crude protein, % DM	6.26	21.32	15.30
Neutral detergent fiber, % DM	53.18	30.10	39.33
Acid detergent fiber, % DM	28.42	10.09	17.42
Lignin, % DM	6.73	2.25	4.04
Starch, % DM	33.93	35.45	34.84
Total digestible nutrients, %	67.94	80.78	75.64
Ca, %	0.11	1.67	1.05
P, %	0.16	0.58	0.41

[1] Premix guarantee levels per kg 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; Fe: 18.00 mg; I: 1.07 mg; Mn: 72.80 mg; Se: 0.64 mg; and Zn: 95.20 mg.

The apparent digestibility coefficient was determined concomitantly with the ingestive behavior analysis. For this, composite samples of the diets of each treatment and total collection of feces of each experimental unit were carried out during the experimental period (48 hours of evaluation). Food collections were performed once a day, following the methodology of collection for two consecutive days and subsequent storage in a freezer. The total fecal collection from each experimental unit was carried out at the end of each shift, with the aid of scrapers, also for two consecutive days, and to avoid interference from dirt, the stalls were washed to remove any and all impurity that could interfere with the collection. Feces were weighed and sampled at each 6-hour shift, and then stored in a freezer at -18ºC until analysis. After the end of the evaluation, samples of diets and feces were thawed, homogenized to form a composite sample, corresponding to each experimental unit. The DM of the diets and feces of each experimental unit were determined using the same procedures adopted for food analysis. The apparent digestibility coefficient of DM of the experimental diets (ADDM) was determined according to the following formula:

$$\text{ADDM}\ (\%) = 1 - \frac{\text{g nutrient ingested} - \text{g nutrient excreted}}{\text{g nutrient ingested}}\ \text{x}\ 100$$

Statistical analysis

For parameters related to animal performance, carcass performance and traits, ingestive behavior and apparent digestibility of the diet, the experiment was a randomized block design, consisting of three treatments, with five repetitions, where each repetition corresponded to a stall with two animals. Data collected for each variable were tested by analysis of variance with comparison of means at 5% significance, in the statistical program Statistical Analysis System Institute [SAS Institute] (1993).

The analysis of each variable for parameters related to animal performance, performance and traits carcass, followed the statistical model: $Y_{ij} = \mu + A_i + B_j + + E_{ij}$; where: Y_{ij} = dependent variables; μ = Overall mean of all observations; Ai = Effect of additives of order "i", where 1 = diet with sodium monensin, 2 = diet with essential oils and tannins, and 3 = diet with essential oils and tannins combined with sodium monensin; Bk = Effect of block of order "k", where 1 = first, 2 = second, 3 = third, 4 = fourth and 5 = fifth; and E_{ij} = Random residual effect.

The analysis of variables referring to the parameters of ingestive behavior and apparent digestibility of the diet, followed the statistical model: $Y_{ijk} = \mu + A_i + M_j + B_k + (A^*M)_{ij} + E_{ijk}$; where: Y_{ijk} = dependent variables; μ = Overall mean of all observations; A_i = Effect of additives of order "i", where 1 = diet with sodium monensin, 2 = diet with essential oils and tannins, and 3 = diet with essential oils and tannins combined with sodium monensin; Mj = Effect of the feedlot moment of order "j", where 1 = first moment and 2 = second moment; Bk = Effect of block of order "k", where 1 = first, 2 = second, 3 = third, 4 = fourth and 5 = fifth; $(A^*M)_{ij}$ = Effect of the interaction between additive and feedlot moment of order "ij" and E_{ij} = Random residual effect.

Results and Discussion

Based on Table 2, it can be seen that supplementation with TAN+EO or MO alone or in combination, regardless of the feedlot time, did not promote changes (P>0.05) on ADG, ADMI, ADMI, %BW and FE, with mean values of 1.442 kg day^{-1}, 10.04 kg day^{-1}, 2.25% body weight and 0.216 kg kg^{-1} at the end of 84 days of feedlot, respectively.

The results obtained indicated the use of TAN+EO supplementation efficiently replaced MO in feedlot-finished steers diets, as well as the combination with MO did not promote a synergistic effect.

Meschiatti et al. (2019) analyzed an EO based on thymol, eugenol, limonene and vanillin at a dose of 90 mg kg^{-1} DM, and observed an increase in DMI by the animals. Pordomingo et al. (2006) evaluated the performance of heifers confined with a high-grain diet, receiving supplementation with MO or TAN (1% quebracho tannin), and reported higher values of ADMI in relation to the group receiving MO. Rivera-Méndez et al. (2016) evaluated the effect of tannins as a supplement for finishing animals, and verified an increase in dry matter intake by 7.1%.

Tabke et al. (2017) when testing a blend of tannins, composed of hydrolysable tannins (*Castanea sativa*) and condensed tannins (*Shinopsis lorentzii*) found no differences in the weight gain of the animals. Cabral et al. (2016) evaluated the inclusion of tannins and monensin, alone and in combination, in the diet of finishing heifers, and observed no differences in the weight gain of the animals, but rather in their efficiency, where those supplemented with tannins alone were more efficient in terms of weight gain than those that received monensin alone or combined with tannin.

Table 2

Animal performance, represented by average daily weight gain (ADG), dry matter intake (DMI), expressed in kg day^{-1} (DMI) or per 100 kg body weight (DMI, BW), feed efficiency (FE) and qualitative fecal score of feedlot finished steers under the effect of the combination of tannins and essential oils alone or combined with sodium monensin in the diet, according to the evaluation periods

Parameters	Experimental feed			Mean	CV	SEM	Probability
	MO	TAN+EO	MO+TAN+EO				
ADG, kg day^{-1}:							
0 to 28 days	1.225 a	1.293 a	1.304 a	1.274	13.99	0.0460	0.7569
0 to 56 days	1.473 a	1.438 a	1.480 a	1.464	11.47	0.0434	0.9121
0 to 84 days	1.417 a	1.407 a	1.501 a	1.442	10.11	0.0376	0.5664
DMI, kg day^{-1}:							
0 to 28 days	9.92 a	10.04 a	9.91 a	9.96	5.89	0.15	0.9309
0 to 56 days	10.09 a	10.20 a	10.13 a	10.14	6.61	0.17	0.9665
0 to 84 days	10.05 a	9.94 a	10.04 a	10.04	7.07	0.18	0.9637
DMI, % BW:							
0 to 28 days	2.28 a	2.31 a	2.29 a	2.29	6.17	0.04	0.9386
0 to 56 days	2.37 a	2.40 a	2.37 a	2.38	4.95	0.03	0.9485
0 to 84 days	2.27 a	2.24 a	2.25 a	2.25	5.15	0.03	0.9409
FE: ADG:DMI, kg kg^{-1}:							
0 to 28 days	0.124 a	0.128 a	0.132 a	0.128	14.89	0.005	0.8059
0 to 56 days	0.145 a	0.140 a	0.145 a	0.144	9.03	0.003	0.8062
0 to 84 days	0.211 a	0.213 a	0.224 a	0.216	7.74	0.004	0.4311
Fecal score, (score):							
0 to 28 days	2.92 a	3.12 a	3.06 a	3.04	3.16	0.03	0.1296
0 to 56 days	2.99 a	2.99 a	2.96 a	2.98	1.87	0.02	0.7229
0 to 84 days	2.73 a	2.81 a	2.86 a	2.80	3.45	0.03	0.1693

Mean values followed by different lowercase letters, in the same row, differ from each other by Tukey's Test at 5%.
CV: Coefficient of variation; SEM: Standard error of the mean.

With the aforementioned inferences, the literature data and the findings in the present study (Table 2), which are related to effects that essential oils and tannins can promote on animal performance, show variations, and these trends are because that the actions of these additives are closely related to the type of oil used, the available substrate, volume administered, the type of binding tannins promote in proteins, the dietary concentration of tannins and proteins and their molecular structures (Patra, 2011; Le Bourvellec & Renarda, 2012).

As already mentioned by Patra (2011) and Jafari et al. (2019), the main action of essential oils is to modulate the bacterial flora, maximize the use of nitrogen and energy from the diet, and the tannins present in the compound increase the concentration of undegraded protein in the rumen, however, the experimental diet did not restrict the supply of protein and energy (Table 1) so that the animals that received the compound of tannins and essential oils were not challenged to the point of showing effects on productive performance. A fact that, according to Valadares et al. (2016) occurs when the dietary protein content is below 12%.

The dry matter content of feces (Table 3) did not change (P>0.05) with the supplementation of different additives. The fecal output, on a dry or natural matter basis, and apparent digestibility of the diet differed between treatments evaluated (P<0.05). The lowest volumes of feces on a dry and natural matter basis were produced when the animals received TAN+EO either alone (2.63 kg day^{-1}; 14.66 kg day^{-1}, respectively) or combined with MO (2.65 kg day^{-1}; 14.70 kg day^{-1}) compared to animals receiving only MO alone (2.93 kg day^{-1}; 17.12 kg day^{-1}). With the same tendency, the apparent digestibility of DM was higher for animals supplemented with TAN+EO and TAN+EO+MO in relation to those that received only MO (70.34% and 70.99% against 68.92% respectively). These parameters were not significantly different between the first and second moments (P>0.05).

The lower feces production is justified by the higher apparent digestibility of the diet, suggesting its better use. Therefore, the improvement in apparent digestibility of the diet in animals receiving TAN and EO suggests an effect of their mechanisms of action, which is to modulate bacterial flora and rumen fermentation, making the rumen more efficient. These findings should be considered positive, as tannins, for example, are considered anti-nutritional factors and are responsible for reducing carbohydrate digestibility, which impairs animal performance (Morales & Ungerfeld, 2015; Tontini et al., 2021).

The ingestive behavior expressed in hours day^{-1} presented in Table 4 shows that the times spent in activities of feed intake, water consumption, rumination and idleness were not altered (P>0.05) with TAN+EO supplementation alone or combined with MO. Likewise, the ingestive behavior expressed in times day^{-1} (Table 5) also did not differ between treatments and evaluation times, for feeding, drinking, liquid excretions, solid excretion and non-ingestive oral behavior, activity in which the animal aims to produce saliva and buffer the rumen pH.

Table 3
Digestive behavior, represented by fecal output in kg day^{-1}, on a natural or dry matter basis, dry matter content of feces and apparent digestibility of dry matter of the feed for feedlot finished steers under the effect of the combination of tannins and essential oils alone or combined with sodium monensin in the diet, according to the feedlot moment

Experimental feed	Confinement period		Mean
	1st Moment	2nd Moment	
	Fecal output, kg animal^{-1} day^{-1} on NM		
MO	17.45	16.79	17.12 A
TAN+EO	15.03	14.29	14.66 B
MO+TAN+EO	15.08	14.31	14.70 B
Mean	15.86 a	15.13 a	
	Dry matter of feces, %		
MO	17.46	16.76	17.11 A
TAN+EO	18.34	17.56	17.95 A
MO+TAN+EO	18.26	18.04	18.15 A
Mean	18.02 a	17.45 a	
	Fecal output, kg animal^{-1} day^{-1} on DM		
MO	3.04	2.81	2.93 A
TAN+EO	2.76	2.51	2.63 B
MO+TAN+EO	2.72	2.57	2.65 B
Mean	2.84 a	2.63 a	
	Apparent digestibility of DM, %		
MO	68.86	68.98	68.92 B
TAN+EO	70.65	70.03	70.34 A
MO+TAN+EO	71.07	70.91	70.99 A
Mean	70.20 a	69.97 a	

Mean values followed by different uppercase letters, in the same column, differ from each other by Tukey’s Test at 5%.
Mean values followed by different lowercase letters, in the same row, differ from each other by F-test at 5%.
NM: Natural matter.

Table 4

Ingestive behavior (hours day⁻¹) of feedlot finished steers under the effect of the combination of tannins and essential oils alone or combined with sodium monensin in the diet, according to the feedlot moment

Experimental feed	Confinement period		Mean
	1st Moment	2nd Moment	
	Feed consumption, hours day^{-1}		
MO	2.34	2.34	2.34 A
TAN+EO	2.55	2.10	2.33 A
MO+TAN+EO	2.60	2.07	2.34 A
Mean	2.50 b	2.17 a	
	Water intake, hours day^{-1}		
MO	0.12	0.20	0.16 A
TAN+EO	0.14	0.15	0.15 A
MO+TAN+EO	0.15	0.13	0.14 A
Mean	0.14 a	0.16 a	
	Rumination, hours day^{-1}		
MO	5.73	5.17	5.45 A
TAN+EO	5.51	4.84	5.18 A
MO+TAN+EO	5.40	4.91	5.16 A
Mean	5.55 a	4.97 a	
	Idle, hours day^{-1}		
MO	15.84	16.31	16.08 A
TAN+EO	15.86	16.93	16.39 A
MO+TAN+EO	15.88	16.96	16.42 A
Mean	15.86 b	16.73 a	

Mean values followed by different uppercase letters, in the same column, differ from each other by Tukey's Test at 5%.
Mean values followed by different lowercase letters, in the same row, differ from each other by F-test at 5%.

Table 5

Ingestive behavior, represented by the frequency of activities performed (times day^{-1}), of feedlot finished steers under the effect of the combination of tannins and essential oils alone or combined with sodium monensin in the diet, according to the feedlot moment

Experimental feed	Confinement period		Mean
	1st Moment	2nd Moment	
	Feeding, times day^{-1}		
MO	13.92	14.33	14.13 A
TAN+EO	14.83	13.08	13.96 A
MO+TAN+EO	14.08	14.67	14.38 A
Mean	14.28 a	14.03 a	
	Water intake, times day^{-1}		
MO	4.92	4.92	4.92 A
TAN+EO	5.00	5.25	5.13 A
MO+TAN+EO	4.75	5.00	4.88 A
Mean	4.89 a	5.06 a	
	Solid excretions, times day^{-1}		
MO	6.50	6.50	6.50 A
TAN+EO	6.83	7.08	6.96 A
MO+TAN+EO	6.00	6.33	6.17 A
Mean	6.44 a	6.64 a	
	Liquid excretions, times day^{-1}		
MO	4.92	4.92	4.92 A
TAN+EO	5.25	5.75	5.50 A
MO+TAN+EO	4.92	5.17	5.04 A
Mean	5.03 a	5.28 a	
	Non-ingestive oral behavior, vezes dia^{-1}		
MO	3.58	3.25	3.42 A
TAN+EO	4.58	3.08	3.83 A
MO+TAN+EO	4.17	3.33	3.75 A
Mean	4.11 a	3.22 a	

Mean values followed by different uppercase letters, in the same column, differ from each other by Tukey's Test at 5%.
Mean values followed by different lowercase letters, in the same row, differ from each other by F-test at 5%.

The lack of significant difference in data obtained from the ingestive behavior demonstrates that, at the levels of inclusion tested, the additives did not physiologically suppress the ingestive activities of the animals, which is positive.

Regarding carcass performance parameters and carcass traits (Tables 6 and 7 respectively), there was a significant effect ($P<0.05$) for the efficiency of conversion of weight gain into carcass (ACG ADG^{-1}, %) and carcass yield. Animals supplemented with MO+TAN+EO were less efficient in converting ingested food into carcass (67.7%) compared to animals supplemented with MO+TAN+EO (73.5%) and/or with TAN+EO (73.8%) that did not differ from each other (Table 6).

Table 6

Carcass performance, represented by the average carcass gain, expressed in kg day^{-1} and in kg equivalent to the total feedlot period, efficiency of conversion of weight gain into carcass (ACG ADG^{-1}, %) and efficiency of transformation of the dry matter intake into carcass (ETDMIC) of feedlot finished steers under the effect of the combination of tannins and essential oils alone or combined with sodium monensin in the diet

Parameters	Experimental feed			Mean	CV	SEM	Probability
	MO	TAN+EO	MO+TAN+EO				
ADCG	1.030 a	1.034 a	1.048 a	1.027	7.95	0.021	0.9511
ACG	86.5 a	86.8 a	85.5 a	86.3	7.97	1.77	0.9530
ACG ADG	73.5 a	73.8 a	67.7 b	71.7	5.25	0.97	0.0471
ETDMIC	9.83 a	9.61 a	9.86 a	9.76	5.70	0.15	0.7510

Mean values followed by different lowercase letters, in the same row, differ from each other by Tukey's Test at 5%.
CV: Coefficient of variation; SEM: Standard error of the mean.

The weight gain of the animals is not only related to the deposition of muscle tissue in the carcass, but also the deposition of fat, whether subcutaneous or visceral, the organs of the animals increase in size and all these parameters are computed in the weight gain. Mezzomo et al. (2016) when administering tannin in the diet of confined cattle, observed greater deposition of muscle tissue, and attributed this fact to the binding of dietary proteins to tannin, which promotes their transport to the intestine, where they will be broken down, and thus increase the availability of amino acids to animals, a component that is converted into muscle.

Table 7
Carcass traits of feedlot finished steers under the effect of the combination of tannins and essential oils alone or combined with sodium monensin in the diet

Parameters	Experimental feed			Mean	CV	SEM	Probability
	MO	TAN+EO	MO+TAN+EO				
Starting live weight (kg)	368.1 a	367.6 a	367.8 a	367.8	2.26	2.15	0.9954
Live slaughter weight (kg)	487.1 a	485.8 a	493.9 a	488.9	3.63	4.58	0.7487
Hot carcass weight (kg)	270.6 a	270.6 a	269.4 a	270.2	3.65	2.54	0.9765
Carcass yield (%)	55.58 ab	55.72 a	54.54 b	55.28	1.22	0.17	0.0325
Fat thickness (mm)	4.3 a	4.4 a	4.4 a	4.4	17.73	0.20	0.9727
Carcass length (m)	1.29 a	1.29 a	1.29 a	1.29	1.71	0.01	0.9865
Cushion thickness (cm)	22.5 a	22.4 a	22.8 a	22.6	5.63	0.33	0.8762
Arm length (cm)	37.7 a	38.6 a	38.1 a	38.1	4.34	0.43	0.7018
Arm perimeter (cm)	47.5 a	47.5 a	47.5 a	47.5	4.73	0.58	0.9909

Mean values followed by different lowercase letters, in the same row, differ from each other by Tukey's Test at 5%.
CV: Coefficient of variation; SEM: Standard error of the mean.

It is suggested that this may have been the main factor that led the animals of the TAN+EO treatment to be more efficient in transforming the weight gain into carcass, and the occurrence of lower efficiency for the animals supplemented with MO+TAN+EO may be due to any antagonistic effect that the additives may have on each other.

Carcass yield (Table 7) was higher for animals supplemented with TAN+EO (55.72%) compared to animals supplemented with MO+TAN+EO (54.54%), but they did not differ from those supplemented with only MO (55 .58%). Results that were due to better efficiency of transformation of weight gain into carcass, as mentioned in Table 6.

In an experiment carried out by Rivaroli et al. (2016), no differences were detected in the carcass yield of animals receiving EO included in the high energy density feed (10% forage and 90% concentrate), but values were close to those of the present study (55.1%). Ebert et al. (2016) evaluated the inclusion of TAN in the diet for crossbred Angus cattle and also found no difference for the parameters of carcass yield and fat thickness.

Hot carcass weight has a high relationship with carcass length (Müller, 1987). The fact that the other variables, arm length, arm perimeter and cushion thickness have a great genetic influence and not the diet or food additive used in it, may have been a determining factor for the lack of difference between treatments, since the animals in the present study had similar racial and genetic patterns. Regarding subcutaneous fat, it is important to point out that the non-occurrence of difference (P>0.05) between treatments in the present study is not something negative, as all of them had subcutaneous fat above 4 mm, which is good because, according to M. R. Silva et al. (2011) when the carcasses reach a minimum value of 3 mm, oxidation during the carcass cooling process is slow, and does not promote changes in quality from meat to its commercialization.

Conclusions

The supplementation of tannins combined with essential oils in the diet for feedlot steers efficiently replaced monensin sodium, resulting in improvements in the apparent digestibility of DM during the finishing phase, not altering the ingestive behavior of the animals and increasing carcass yield.

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