Brazilian red pepper leaves essential oil (Schinus terebinthifolius) in diets for feedlot lambs

Óleo essencial das folhas de aroeira (Schinus terebinthifolius) em dietas para cordeiros confinados

Analisa Vasques Bertoloni¹; Daniel Montanher Polizel²; Marcos Vinícius de Castro Ferraz Júnior³; Gabriela Bagio Oliveira¹; Alexandre Arantes Miszura¹; José Paulo Roman Barroso³; André Storti Martins¹; Lairana Aline Sardinha¹; Armando Cintra Limeired¹; Evandro Maia Ferreira²; Alexandre Vaz Pires¹,²

¹ Universidade de São Paulo, Faculdade de Medicina Veterinária e Zootecnia, Departamento de Nutrição e Produção Animal, Pirassununga – SP, Brazil
² Universidade de São Paulo, Escola Superior de Agricultura “Luiz de Queiroz”, Departamento de Zootecnia, Piracicaba – SP, Brazil
³ Universidade Federal do Amazonas, Parintins – AM, Brazil

ABSTRACT
Essential oil (EO) from Brazilian red pepper leaves contains antimicrobial compounds that control Gram-positive bacteria in the rumen content, improving the efficiency of ruminal fermentation. The objectives of the present study were to evaluate the effects of the Brazilian red pepper leaves EO (Schinus terebinthifolius) as a substitute for monensin on performance, occurrence of coccidiosis by *Eimeria ssp.*, carcass characteristics and meat composition of feedlot lambs. Forty-four lambs, 16 males (12 ½ Dorper × ½ Santa Inês and 4 Santa Inês) and 28 females (16 ½ Dorper × ½ Santa Inês and 12 Santa Inês), with 21.4 ± 1.05 kg of initial body weight (BW), were used in a randomized complete block design. The experiment lasted 56 days, divided into 2 periods of 28 days each. The treatments were defined by the inclusion of 8 ppm of monensin (MON), and the doses 0.14% (14EO), 0.28% (28EO) and 0.42% (42EO) of red pepper leaves essential oil (EO). At the end of 56 days, 32 lambs were slaughtered for the measurement of carcass parameters and meat composition. There was no interaction among treatments and periods for average daily gain (ADG), dry matter intake (DMI), feed efficiency (FE) and oocyst of *Eimeria ssp.* in feces. The treatments did not affect the ADG, DMI and FE; however, the monensin inclusion decreased the oocyst of *Eimeria ssp.* (*P* = 0.01). There was a tendency (*P* = 0.06) of increase in hot carcass yield for lambs fed 28EO compared to 14EO. In addition, the cold carcass yield was higher (*P* = 0.02) in the animals fed 28EO and 42EO. The subcutaneous fat thickness was not affected by the experimental diets; however, there was a tendency for lambs from 28EO and 42EO treatments to present higher body wall thickness (*P* = 0.07) and Longissimus muscle area (*P* = 0.07) when compared to MON. The higher doses of red pepper leaves EO increased the percentage of crude protein (*P* < 0.01) and mineral matter (*P* = 0.02) in the chemical composition of meat. Although the performance of lambs did not change, the inclusion of 0.28 and 0.42% red pepper leaves EO improve the carcass characteristics and change the meat composition, demonstrating the potential of the use of this additive in confined lamb diets. However, the monensin has greater potential to control coccidiosis in feedlot lambs compared with red pepper leaves EO.

Keywords: Additives. Performance. Ionophore. Vegetal extracts.

RESUMO
O óleo essencial das folhas da aroeira possui compostos antimicrobianos que controlam a população de bactérias gram-positivas presentes no conteúdo ruminal, melhorando a eficiência do processo de fermentação. Os objetivos do presente estudo foram avaliar os efeitos do óleo essencial das folhas da aroeira (Schinus terebinthifolius) em substituição a monensina sobre o desempenho, ocorrência de coccidiose por *Eimeria ssp.*, características de carcaça e da carne de cordeiros confinados. Quarenta e quatro cordeiros, 16 machos (12 ½ Dorper × ½ Santa Inês e 4 Santa Inês) e 28 fêmeas (16 ½ Dorper × ½ Santa Inês e 12 Santa Inês), com 21,4 ± 1,05 kg de peso inicial, foram utilizados em delineamento de blocos completos ao acaso. O experimento teve duração de 56 dias, divididos em 2 períodos de 28 dias cada. Os tratamentos foram definidos pela inclusão de 8 ppm de monensina sódica (MON) e as doses 0,14% (14OE), 0,28% (28OE) e 0,42% (42OE) do óleo essencial (OE) das folhas da aroeira. Ao final dos 56 dias, 32 animais foram abatidos para...
Introduction

High energy diets are provided in confined breeding system aiming to maximize animal performance. High concentrate diets for feedlot lambs provide enough energy and protein for weight gain over 250 g/d (Ferreira et al., 2011; Polizel et al., 2017). The use of feed additives that modulate ruminal fermentation is important, improving the propionate production and reducing the damage caused by some rumen microorganisms (Owens et al., 1998), since the inclusion of high levels of concentrate may hinder rumen fermentation (Nagaraja et al., 1997).

Monensin is the main ionophore used in ruminant nutrition, resulting in an increase in energy retention and dietary nitrogen use (Tedeschi et al., 2003), changes in molar concentration of short chain fatty acids (Ellis et al., 2012), decrease in dry matter intake (DMI) and increase in average daily gain (ADG) and feed efficiency (FE) (Duffield et al., 2012). Ionophores are classified as antibiotics by the Food and Drug Administration, but are not used in human medicine. The interest in exploring natural products that pose no health risks and can be used as feed additives has increased. Due to the ban on the use of ionophores as growth promoters in animal feed carried out by the European Union, there is increased interest in alternative feed additives.

Some essential oils have a similar capacity to the ionophores, acting selectively on the microbial populations of the rumen (Calsamiglia et al., 2007). The use of EO and their bioactive compounds results in a change in the fermentation pattern, reducing the acetate:propionate ratio and the methane production, making rumen more efficient (Khioasa-ard & Zebeli, 2013). From the Brazilian red pepper (Schinus terebinthifolius), it is possible to extract EO from the leaves, fruits and trunk, with the main substances found including α-pinene, sabineno, β-pinene, α-felandreno, Δ-3-carene, β-felandreno, α-copaene, germacrene-D, bicyclogermacrene, β-caryophyllene and δ-cadinene (Barbosa et al., 2007; Santos et al., 2007).

Therefore, it has been hypothesized that Brazilian red pepper leaves EO could be included in diets for feedlot lambs as a feed additive, resulting in similar response compared with monensin. The objective of this study was to evaluate the effects of the inclusion of red pepper leaves EO as a substitute for monensin on performance, occurrence of coccidiosis by Eimeria ssp., carcass characteristics and meat composition of lambs.

Material and Methods

Forty-four lambs were used, 16 male (12 ½ Dorper × ½ Santa Inês and 4 Santa Inês) and 28 female (16 ½ Dorper × ½ Santa Inês and 12 Santa Inês), with 21.4 ± 0.10 kg of initial body weight (BW).
The experiment consisted of a 56-d period, divided into two 28-d periods. The animals were weighed after 14 h of solid fasting period on d 0, 28 and 56 of the experiment. The experiment design used was randomized complete blocks, each block defined by sex, breed and initial BW. The lambs were kept indoors, in an individual tie-stall system, with a slatted floor, feed bunk, and waterer. On d 28 and 56, feces samples were collected to evaluate the coccidiosis oocyst *Eimeria* *ssp.* (COC) (Gordon & Whitlock, 1939).

The experimental diets were defined by the addition of monensin (Rumensin 200, Elanco Animal Health, São Paulo, SP, Brazil), or doses of red pepper leaves EO (Lazlo Aromaterapia, Belo Horizonte, MG, Brazil). The experimental diets were as follows: inclusion of 8 mg of monensin/kg of DM (MON); diets with 0.14% (14EO), 0.28% (28EO) and 0.42% of red pepper leaves EO (42EO; Table 1). The red pepper leaves EO composition was performed by gas chromatography coupled to mass spectrometry provided with an automatic injector, using a capillary column with 30 meters in length and 25 mm internal diameter. The total chromatographic run time was 60 min, divided into five heating cycles, as follows: 50 °C (30 min), 200 °C (4 °C/min), 240 °C (10 °C/min), 280 °C (10 °C/min), and 290 °C (5 °C/min).

The total mixed diets were offered ad libitum once a day. The experimental diets were prepared weekly to avoid possible changes in the compounds present in the EO. Orts were recorded daily to determine the DMI, and the refused feed did not exceed 5% of daily intake. In each experimental period (28d), ADG and feed efficiency were calculated.

The DM and ash content were determined according to Association of Official Analytical Chemists (1990). Sequential detergent fiber analyses were determined according to Van Soest et al. (1991). Total N and ether extract of the diets and meat were determined according to the Association of Official Analytical Chemists (1990). Non fiber carbohydrates of the diets were estimated according to the following equation: NFC (%) = 100% - (% NDF + %CP + % fat + % ash).

At the end of the 56 days, 32 lambs (16 male and 16 female) were slaughtered, following the norms described in the Regulation of the Industrial and Sanitary Inspection of Products of Animal Origin - RIISPOA. The lambs were weighed after 14 h fasting period to obtain the slaughter weight (SW). Carcass characteristics evaluated were hot carcass weight (HCW) and hot carcass yield (HCY), obtained at the time of slaughter. After 24 h of chilling (4 °C), the chilled carcass weight (CCW), chilled carcass yield (CCY), subcutaneous fat thickness over the 12th rib (SFT), body wall thickness (BWT), and *Longissimus dorsi* muscle area (LM area) were obtained. Approximately 15 cm samples of the *Longissimus dorsi* muscle from the right half carcass of each animal were collected and stored at -18 °C for determination of the chemical composition of the meat. The DM, ash, total N and ether extract content of the *Longissimus dorsi* meat were determined according to Association of Official Analytical Chemists (1990).

Statistical analyses were performed using the MIXED procedure of the SAS (SAS version 9.0; SAS Inst. Inc., Cary, NC, USA). All data were submitted to the Shapiro-Wilk test to check the normality of the residuals and the removal of

### Table 1 – Proportion of the ingredients and chemical composition of the experimental diets containing monensin or Brazilian red pepper leaves EO (Piracicaba, 2019)

| Item                                    | MON   | 14EO  | 28EO  | 42EO  |
|-----------------------------------------|-------|-------|-------|-------|
| Ingredient, % of DM                     |       |       |       |       |
| Coastcross hay                          | 10.00 | 10.00 | 10.00 | 10.00 |
| Ground corn                             | 72.00 | 71.86 | 71.72 | 71.58 |
| Soybean meal                            | 14.00 | 14.00 | 14.00 | 14.00 |
| Urea                                    | 0.50  | 0.50  | 0.50  | 0.50  |
| Mineral premix                          | 1.50  | 1.50  | 1.50  | 1.50  |
| Ammonium chloride                       | 0.50  | 0.50  | 0.50  | 0.50  |
| Limestone                               | 1.50  | 1.50  | 1.50  | 1.50  |
| Red pepper leaves EO                    | 0.00  | 0.14  | 0.28  | 0.42  |
| Monensin, ppm                           | 8.00  | 0.00  | 0.00  | 0.00  |
| Chemical composition                     |       |       |       |       |
| DM, as-fed basis                        | 87.45 | 87.33 | 87.60 | 87.62 |
| Ash, % DM                               | 5.40  | 5.41  | 5.59  | 5.71  |
| CP, % DM                                | 19.26 | 18.71 | 19.11 | 19.11 |
| NDF, % DM                               | 19.05 | 18.05 | 18.39 | 18.61 |
| ADF, % DM                               | 7.75  | 7.40  | 7.38  | 7.66  |
| Ether extract, % DM                     | 4.67  | 3.59  | 3.97  | 3.86  |
| NFC, % DM                               | 51.62 | 54.24 | 52.94 | 52.71 |

1MON = diet containing 8 mg of monensin/kg of DM; 14EO = inclusion of 0.14% of red pepper leaves EO (DM basis); 28EO = inclusion of 0.28% of red pepper leaves EO; 42EO = inclusion of 0.42% of red pepper leaves EO; 2DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; NFC = non-fiber carbohydrate.
“outliers” and the Levene test to verify the homogeneity of variances. The animals were considered as the experimental unit to perform statistical analyses. The treatment means were obtained by the LSMEANS command. The treatment effect was defined by Tukey test. The period effect and treatment x period interaction were defined by the F test. Statistical significance was declared at $P \leq 0.05$, with trends noted at $P > 0.05$ to $P < 0.10$.

**Results**

The main components found in the red pepper leaves EO used in the present study were Δ-3-carene (28.7%), limonene (17.5%), α-pinene (11.1%), α-felandrene (8.3%), p-cimene (6.1%), α-elemol (3.9%), β-cariofilene (3.5%), mircene (3.0%) and germacrene D (2.5%). In addition, the compounds used in the present study were Δ-3-carene (28.7%), limonene

### Table 2 – Performance and oocyst count of feedlot lambs fed high-concentrate diets containing monensin or Brazilian red pepper leaves EO (Piracicaba, 2019)

| Item | MON | 14EO | 28EO | 42EO | SEM | Diets | P-value | $D \times P$ |
|------|-----|------|------|------|-----|-------|---------|-----------|
| BW, kg | 21.36 | 21.37 | 21.32 | 21.36 | 1.05 | -     | -       | -         |
| ADG, g | 236.20 | 265.50 | 262.99 | 271.92 | 21.71 | 0.17 | 0.50 | 0.24 |
| DMI, g/dia | 904.66 | 943.27 | 964.08 | 952.35 | 42.22 | 0.26 | <0.01 | 0.40 |
| FE, gain:feed | 0.261 | 0.289 | 0.273 | 0.285 | 0.01 | 0.20 | <0.01 | 0.12 |
| Oocysts/g | 4.11 | 17.44 | 19.35 | 17.24 | 3.47 | 0.01 | <0.01 | 0.14 |

1) MON = diet containing 8 mg of monensin/kg of DM; 14EO = inclusion of 0.14% of red pepper leaves EO (DM basis); 28EO = inclusion of 0.28% of red pepper leaves EO; 42EO = inclusion of 0.42% of red pepper leaves EO; SEM = standard error of the means; $P$ = period effect; $D \times P$ = diets and periods interaction; 2) ADG = average daily gain; DMI = dry matter intake; FE = feed efficiency; 3) means in the same row with different superscripts differ $(P \leq 0.05)$; *means in the same row with different superscripts tented to differ $(P > 0.05$ to $P < 0.10)$.

### Table 3 – Carcass characteristics and meat composition of feedlot lambs fed high-concentrate diets containing monensin or Brazilian red pepper leaves EO (Piracicaba, 2019)

| Item | MON | 14EO | 28EO | 42EO | SEM | Diets | P-value | $D \times P$ |
|------|-----|------|------|------|-----|-------|---------|-----------|
| Slaughter weight, kg | 37.66 | 39.64 | 38.35 | 38.50 | 1.56 | 0.27 |
| Carcass characteristics | | | | | | |
| HCW, kg | 18.59 | 19.36 | 19.74 | 19.53 | 0.83 | 0.28 |
| HCY, % | 49.06 | 48.84 | 51.53 | 50.92 | 0.78 | 0.06 |
| CCW, kg | 17.69 | 18.94 | 19.26 | 19.41 | 0.83 | 0.06 |
| CCB, % | 47.94 | 47.76 | 50.29 | 50.64 | 0.74 | 0.02 |
| BWT, mm | 13.78 | 15.58 | 15.71 | 16.50 | 0.88 | 0.07 |
| SFT, mm | 1.23 | 1.16 | 1.12 | 1.44 | 0.16 | 0.50 |
| LM area, cm² | 12.80 | 14.15 | 14.55 | 14.71 | 0.64 | 0.07 |
| Meat composition, % | | | | | | |
| DM | 25.72 | 25.40 | 25.88 | 25.90 | 0.27 | 0.52 |
| CP | 23.23 | 22.81 | 24.25 | 23.60 | 0.16 | <0.01 |
| Ash | 1.27 | 1.25 | 1.26 | 1.33 | 0.02 | 0.02 |
| Ethanol extract | 2.97 | 2.84 | 2.62 | 2.98 | 0.23 | 0.66 |

1) MON = diet containing 8 mg of monensin/kg of DM; 14EO = inclusion of 0.14% of red pepper leaves EO (DM basis); 28EO = inclusion of 0.28% of red pepper leaves EO; 42EO = inclusion of 0.42% of red pepper leaves EO; SEM = standard error of the means; Diets = fixed effect of the experimental diets; HCY = hot carcass weight; HCY = hot carcass yield; CCW = chilled carcass weight; CCB = chilled carcass yield; BWT = body wall thickness; SFT = subcutaneous fat thickness; LM area = Longissimus muscle area; DM = dry matter; CP = crude protein; *means in the same row with different superscripts differ $(P \leq 0.05)$; *means in the same row with different superscripts tented to differ $(P > 0.05$ to $P < 0.10)$. 

There was no interaction between treatment and period effects for ADG, DMI and oocyst of *Eimeria ssp* (Table 2). The experimental diets did not affect the ADG, DMI, FE and BW at 28 d and 56 d. Period effect was observed for DMI $(P < 0.01)$ and FE $(P < 0.01)$, in which the DMI increased during the experiment (P1: 878.57 ± 38.07 and P2: 1003.71 ± 40.46 g/d), and, consequently, the FE during the first period was higher than the second period (P1: 0.29 ± 0.01 and P2: 0.25 ± 0.01).

Lambs fed MON had lower oocyst $(P = 0.01)$ when compared with lambs fed red pepper leaves EO. In addition, the oocyst count was higher in the first period (70.4 oocysts/g) when compared with the second period (11.4 oocysts/g).

The experimental diets did not affect slaughter weight, HCW and SFT (Table 3). However, the 28EO and 42EO diets...
tended to increase the HCY \((P = 0.06)\) compared with 14EO and tended to increase CCW \((P = 0.06)\), BWT \((P = 0.07)\) and LM area \((P = 0.07)\) when compared with MON. The higher doses of red pepper leaves EO increased CP on meat \((P < 0.01)\) when compared with MON and 14EO. In addition, 42EO increased the meat ash content \((P = 0.02)\) compared with 14EO.

The experimental diets did not affect the DM and EE of the meat. However, the diets containing 0.28% of red pepper leaves EO increased CP on meat \((P < 0.01)\) when compared with MON and 14EO. In addition, 42EO increased the meat ash content \((P = 0.02)\) compared with 14EO.

**Discussion**

During the extraction process, the same raw material is subject to factors that may change its composition, such as the maturation stage of the plant, climatic and agronomic conditions, extraction process (Marco et al., 2007; Quispe Condori et al., 2008). Thus, although the literature describes the main compounds already identified in the red pepper leaves EO, there is a great variation in the data on the concentration of each one of these compounds, which may interfere in the effects of the EO use. Araújo (2010) reported that EO extracted from red pepper leaves presented 58.4% of α-pinene, 15.7% of β-pinene and 13% of limonene, while Faleiro (2015) reported the concentration of 40.2% α-pinene, 16.2% P-cymene and 11.3% β-pinene in red pepper leaves EO. In the present study, the three compounds identified in the highest concentrations were Δ-3-carene, limonene and α-pinene and it is not possible to establish the effects independent of these components on animal performance, since several compounds can act in synergy and there are no studies that report the isolated effects of these in animal performance.

When used in association with other compounds (thymol, eugenol and vanillin) as supplement for growing beef cattle fed a silage-based diet, limonene showed similar FE to monensin-supplemented animals, which were higher than control animals (Benchaar et al., 2006). In a study with juniper oil, which contained 35% α-pinene, an increase in ADG of lambs was observed when compared to control animals (Chaves et al., 2008). Some EO can manipulate the ruminal fermentation process (Araújo, 2010; Faleiro, 2015), as well as monensin (Bergen & Bates, 1984). This may explain the performance of the lambs that received EO not being different from those on MON treatment.

Some EO may decrease the total mixed ration acceptability, reducing the DMI (Calsamiglia et al., 2007), and four volatile compounds evaluated individually were related to intake, camphor, α-pinene, camphene, and caryophyllene oxide (Estell et al., 2008). Although red pepper leaves EO used in this study presented a characteristic and marked odor and high concentration of α-pinene (11.1%), the doses used did not affect DMI when compared to the diet containing monensin.

Although, in the present study, the EO could be considered a possible substitute for monensin, these antibiotics have a coccidiostatic capacity, controlling the intestinal population of *Eimeria spp.*, and in many cases, coccidiosis infestation is not evaluated on the studies (Chaves et al., 2008, 2011). Lambs that received diets with red pepper leaves EO showed higher infestation by *Eimeria spp.* when compared to lambs fed with MON. In addition, a greater number of oocysts/g of feces were observed in the first experimental period, when the lambs were recently weaned, a stressing factor, which could impair the immune response and to promote the occurrence of the disease (Chartier & Paraud, 2012). As the animals got older, they may have acquired resistance, since in healthy animals kept under adequate management conditions, the continuous intake of oocysts in a small amount causes the development of protective immune response, which limits the infection but does not eliminate it totally (Amarante, 2015). Another factor that may have contributed to the reduction of infestation of lambs over time was the type of floor on which they were kept, which was made of slats, easily drained, reducing the contact of lambs with feces. Even though oocyst infestation was higher in EO treatments, it is possible that this oil has no effect on this parasite. It is important to emphasize that the administration of monensin and lasalocid, mixed with the feed, is usually quite efficient in the prevention of coccidiosis in ruminant animals (Amarante, 2015).

The performance and carcass characteristics are directly influenced by the nutritional composition of the diet (Gonzaga et al., 2006). In the present study, the inclusion of monensin or EO in diets did not affect the slaughter weight of lambs, which may have been a consequence of similar performance among treatments during the experimental period. However, with the data obtained in this study, it is possible to suggest that the high doses of red pepper leaves EO were able to increase the energy availability of the diet for the lambs, thus increasing the CCY, as well as the deposition of fat, as observed with the increase in BWT. The data also suggest that the use of EO may have generated metabolic changes in lambs, directly affecting the carcass composition, as observed in the increase in LM area of lambs fed the highest EO doses.

The values obtained for SFT in the present study may be considered lower for Dorper x Santa Inês crossbreed (Souza et al., 2013). Nevertheless, the protein content in

Braz J Vet Res Anim Sci. 2020;57(1):e157580
the experimental diets presented high levels, which may have influenced the low-fat deposition, since the muscle growth and the deposition of adipose tissue are directly related to the protein levels ingested by the animal.

The increased in LM area and protein content in the meat of lambs fed higher doses of red pepper leaves EO can be explained by the availability of protein for the ruminant post-absorptive metabolism. Meschiatti et al. (2019) described that the blend EO did not affect the nitrogen intake compared with diets containing monensin; however, an increase in protein digestibility and nitrogen absorbed was observed when blend EO was used.

Conclusion

Although it did not affect the performance of the lambs, the use of higher doses of red pepper leaves EO resulted in greater effects on the carcass and meat characteristics, showing the potential of the use the EO in feedlot lambs fed high concentrate diets. However, it is important to consider that the monensin was more efficient in controlling the number of oocysts of *Eimeria ssp.* in feces of lambs compared with red pepper leaves EO. As a suggestion, it is necessary to study the efficiency of use of Brazilian red pepper leaves OE for feedlot lambs in relation to diets with no feed additives inclusion.

Conflict of Interest

We have no conflict of interest to declare.

Ethics Statement

The ethics committee approval certificate is attached (CEUA n° 5468211016).

Acknowledgements

The authors thank Coordination for the Improvement of Higher Education Personnel (CAPES) for a scholarship to Analisa Vasques Bertoloni.

References

Amarante AFT. Os parasitas de ovinos. 1a ed. São Paulo: Editora Unesp Digital; 2015. 266 p.

AOAC: Association of Official Analytical Chemists. Official methods of analyses. 16th ed. Washington: AOAC; 1990.

Araújo RC. Essential oils from Brazilian plants as *in vitro* rumen fermentation modiefers [thesis]. São Paulo: Escola Superior de Agricultura “Luiz de Queiroz”; Universidade de São Paulo; 2010.

Barbosa LCA, Demuner AJ, Clemente AD, Paula VF, Ismail FMD. Seasonal variation in the composition of volatile oils from *Schinus terebinthifolius* Raddi. Quim Nova. 2007;30(8):1959-65. http://dx.doi.org/10.1590/S0100-40422007000800030.

Benchear C, Duynisveld JL, Charmley E. Effects of monensin and increasing dose levels of a mixture of essential oil compounds on intake, digestion and growth performance of beef cattle. Can J Anim Sci. 2006;86(1):91-6. http://dx.doi.org/10.4141/A05-027.

Bergen WG, Bates DB. Ionophores: their effect on production efficiency and mode of action. J Anim Sci. 1984;58(6):1465-83. http://dx.doi.org/10.2527/jas1984.5861465x. PMid:6378864.

Calsamiglia S, Busquet M, Cardozo PW, Castillejos L, Ferret A. Invited review: essential oils as modifiers of rumen microbial fermentation. J Dairy Sci. 2007;90(6):2580-95. http://dx.doi.org/10.3168/jds.2006-644. PMid:17517698.

Chartier C, Paraud C. Coccidiosis due to *Eimeria* in sheep and goats, a review. Small Rumin Res. 2012;103(1):84-92. http://dx.doi.org/10.1016/j.smallrumres.2011.10.022.

Chaves AV, Dugan MER, Stanford K, Gibson LL, Bystrom JM, McAllister TA, Van Herk F, Benchear CA. A dose-response of cinnamaldehyde supplementation on intake, ruminal fermentation, blood metabolites, growth performance, and carcass characteristics of growing lambs. Livest Sci. 2011;141(2-3):213-20. http://dx.doi.org/10.1016/j.livsci.2011.06.006.

Chaves AV, Stanford K, Dugan MER, Gibson LL, McAllister TA, Van Herk F, Benchear C. Effects of cinnamaldehyde, garlic and juniper berry essential oils on rumen fermentation, blood metabolites, growth performance, and carcass characteristics of growing lambs. Livest Sci. 2008;117(2-3):215-24. http://dx.doi.org/10.1016/j.livsci.2007.12.013.

Duffield TF, Merrill JK, Bagg RN. Meta-analysis of the effects of monensin in beef cattle on feed efficiency, body weight gain and dry matter intake. J Anim Sci. 2012;90(12):4583-92. http://dx.doi.org/10.2527/jas.2011-5018. PMid:22859759.
Ellis JL, Dijkstra J, Bannink A, Kebreab E, Hook SE, Archibeque S, France J. Quantifying the effect of monensin dose on the rumen volatile fatty acid profile in high-grain-fed beef cattle. J Anim Sci. 2012;90(8):2717-26. http://dx.doi.org/10.2527/jas.2011-3966. PMid:22896736.

Estell RE, Fredrickson EL, Anderson DM, Remmenga MD. Effects of cis-β-ocimene, cis-sabinene hydrate, and monoterpene and sesquiterpene mixtures on alfalfa pellet intake by lambs. J Anim Sci. 2008;86(6):1478-84. http://dx.doi.org/10.2527/jas.2007-0699. PMid:18272857.

Faleiro JA No. Impact of essential oils of Brazil plants on ruminal parameters fermentation, digestibility and nitrogen balance in sheep [thesis]. São Paulo: Faculdade de Medicina Veterinária e Zootecnia, Universidade de São Paulo; 2015.

Ferreira EM, Pires AV, Susin I, Mendes CQ, Gentil RS, Araújo RC, Amaral RC, Loerch SC. Growth, feed intake, carcass characteristics, and eating behavior of feedlot lambs fed high-concentrate diets containing soybeans hulls. J Anim Sci. 2011;89(12):4120-6. http://dx.doi.org/10.2527/jas.2010-3417. PMid:21666006.

Gonzaga S No, Silva AG So, Zeola NMBL, Marques CAT, Silva AMDA, Pereira JM Fo, Ferreira ACD. Características quantitativas da carcaça de cordeiros deslanados Morada Nova em função da relação volumoso:concentrado na dieta. Rev Bras Zootec. 2006;35(4):1487-95. http://dx.doi.org/10.1590/S1516-35982006000500031.

Gordon HM, Whitlock HV. A new technique for counting nematode eggs in sheep feces. J Counsc Sci Ind Res. 1939;12(1):50-2.

Khiosa-ard R, Zebeli Q. Meta-analysis of the effects of essential oils and their bioactive compounds on rumen fermentation characteristics and feed efficiency in ruminants. J Anim Sci. 2013;91(4):1819-95. http://dx.doi.org/10.1590/S1516-35982006000500031.

Marco CA, Inneco R, Mattos SH, Borges NSS, Nagao EO. Essential oil characteristics from citronella grass depending on planting space, cutting height and harvesting time. Hortic Bras. 2007;25(3):429-32. http://dx.doi.org/10.1590/S0102-05362007000300020.

Meschiatti MAP, Gouveia VN, Pellarin LA, Batalha CDA, Biehl MV, Acedo TS, Dórea JRR, Tamassia LFM, Owens FN, Santos FAP. Feeding the combination of essential oils and exogenous α-amylase increases performance and carcass production of finishing beef cattle. J Anim Sci. 2019;97(1):456-71. http://dx.doi.org/10.1093/jas/sky415. PMid:30351389.

Nagaraja TG, Newbold CJ, Van Nevel CJ, Demeyer DI. Manipulation of ruminal fermentation. In: Hobson PN, Stewart CS, editors. The rumen microbial ecosystem. 2nd ed. London: Chapman & Hall; 1997. p. 523-632. http://dx.doi.org/10.1007/978-94-009-1453-7_13.

Owens FN, Secrist DS, Hill WJ, Gill DR. Acidosis in cattle: a review. J Anim Sci. 1998;76(1):275-86. http://dx.doi.org/10.2527/jas1998.761275x. PMid:9464909.

Polizel DM, Susin I, Gentil RS, Souza RA, Freire APA, Pires AV, Ferraz MVC Jr, Rodrigues PHM, Eastridge ML. Crude glycerin decreases nonesterified fatty acid concentration in ewes during late gestation and early lactation. J Anim Sci. 2017;95(2):875-83. http://dx.doi.org/10.2527/jas2016.0999. PMid:28380605.

Quispe-Condori S, Foglio MA, Rosa PTV, Meireles MAA. Obtaining β-caryophyllene from Cordia verbenacea de Candolle by supercritical fluid extraction. J Supercrit Fluids. 2008;46(1):27-32. http://dx.doi.org/10.1016/j.supflu.2008.02.015.

Santos ACA, Rossato M, Agostini F, Santos PL, Serafinita LA, Moyna P, Dellacassa E. Monthly chemical evaluation of three specimens of Schinus terebinthifolius Radii. Rev Bras Biociênc. 2007;5(2):1011-3.

Souza DA, Selaive-Villarroel AB, Pereira ES, Osório JCS, Teixeira A. Growth performance, feed efficiency and carcass characteristics of lambs produced from Dorper sheep crossed with Santa Inês or Brazilian Somali sheep. Small Rumin Res. 2013;114(1):51-5. http://dx.doi.org/10.1016/j.smallrumres.2013.06.006.

Tedeschi LO, Fox DG, Tylutki TP. Potential environmental benefits of ionophores in ruminant diets. J Environ Qual. 2003;32(5):1591-602. http://dx.doi.org/10.2134/jeq2003.1591. PMid:14535299.

Van Soest PJ, Robertson JB, Lewis BA. Symposium: carbohydrate methodology, metabolism, and nutritional implications in dairy cattle: methods for dietary fiber, neutral detergent fiber, and non starch polysaccharides in relation to animal nutrition. J Dairy Sci. 1991;74(10):3583-97. http://dx.doi.org/10.3168/jds.S0022-0302(91)78551-2. PMid:1660498.

Financial Support: None.