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Zeolite supplementation effects on lamb growth and gastrointestinal nematode infection, and economic analysis[1]

Efeitos da suplementação com zeólita sobre o crescimento de cordeiros, infecção de nematoides gastrointestinais e análise econômica

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ABSTRACT - Zeolite as a dietary supplement can improve animal resistance and resilience against gastrointestinal parasites. The effects of different levels of zeolite supplementation on gastrointestinal nematode infection, growth performance, and economic viability of male and female Santa Ines lambs were investigated. Four zeolite levels (0, 25, 50, and 75 g per day) were fed to 110 day-old animals in a randomized block experimental design. Eggs per gram of feces (EPG), total serum protein (TSP), and packed cell volume (PCV) were measured individually every week. The animals were weighed every 14 days and coprocultures were prepared. Male animals that reached an average live weight of 34 kg were harvested. The economic viability analysis of the experimental diets was based on feedlot periods of 56 and 91 days. Dietary supplementation with zeolite did not significantly mitigate infections by nematodes and did not affect TSP, PCV, or feedlot lamb growth performance. Therefore, zeolite was not an effective ($P > 0.05$) dietary supplement for avoiding gastrointestinal nematode infection or improving growth performance. Male animals slaughtered after 56 days of feeding were more economically viable ($P < 0.05$) than those slaughtered after 91 days. Feedlotting demonstrated that male animals had superior performance ($P < 0.05$) and better economic ($P < 0.05$) results than female animals.

Key words: Stilbite. Santa Inês lamb. Meat production. Performance. Profit.

RESUMO - O uso de zeólita na suplementação alimentar pode melhorar a resistência e resiliência aos parasitas gastrintestinal. Os efeitos da suplementação nutricional com zeólita de cordeiros Santa Inês no desempenho, crescimento, infecção por nematoides gastrintestinais e análise econômica foram investigados. Animais fêmeas e machos de 110 dias foram suplementados com quatro níveis de zeólita: 0, 25, 50, e 75 gramas por dia em um delineamento experimental em blocos ao acaso. Os ovos por grama de fezes (OPG), proteína sérica total (PST) e volume globular (VG) foram obtidos de cada animal semanalmente. A cada 14 dias os animais foram pesados e as coproculturas preparadas. Foram abatidos os machos que atingiram peso vivo médio de 34 kg. A análise de viabilidade econômica das dietas foi baseada nos períodos de confinamento de 56 e 91 dias. A zeólita não mitigou significativamente ($P > 0,05$) a infecção por nematoides, não afetou a PST, o PCV e o desempenho dos cordeiros confinados. A zeólita não foi um suplemento dietético eficiente para evitar a infecção por nematoides gastrintestinais ou melhorar o desempenho dos cordeiros. Os machos abatidos aos 56 dias de confinamento apresentaram maior viabilidade econômica ($P < 0,05$) comparados àqueles abatidos aos 91 dias. Os machos confinados tiveram desempenho superior ($P < 0,05$) e melhores resultados econômicos ($P < 0,05$) comparados às fêmeas. O aumento do período de confinamento reduziu a lucratividade.

Palavras-chave: Estilbita. Cordeiro Santa Inês. Produção de carnes. Desempenho. Lucro.

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INTRODUCTION

Zeolites are crystalline, hydrated aluminosilicates from the group of alkali and alkaline earth cations that exhibit porosity characteristics allowing for the exchange of water, cations, and molecules undergoing structural changes (PAPAIOANNOU *et al*., 2005). Considering the zeolite peculiarities, the mineral has been employed in various industrial and agricultural processes as an additive to animal nutrition (BERNARDI *et al*., 2013; MUMPTON, 1999). Natural zeolites work as NH_4^+ reservoirs in the rumen, enabling the continuous synthesis of microbial proteins (MUMPTON, 1999; RIBEIRO *et al*., 2014). The favorable effects of using these minerals for dietary supplementation have been previously demonstrated, particularly in relation to ruminant growth. According to Mumpton (1999), supplementation of animal diets with zeolite facilitated a 20% to 30% increase in the feed conversion rate or maintained the same weight gain as that of a non-supplemented diet, only with smaller quantities of food and water. Valpotic *et al*. (2017) indicated a rate of 3.0% (zeolite dose per dietary dry matter) to ensure the greatest daily weight gain of lambs. Nevertheless, Câmara *et al*. (2012) showed no improvement in the urea used in beef cattle diets using up to 3.0% zeolite, based on the dietary dry matter, as there was no change in the intake and digestibility of nutrients or ruminal parameters evaluated.

As protein levels in the diet influence an animal's resistance and resilience to gastrointestinal parasites (BRICARELLO *et al*., 2015), the use of minerals that improve digestive efficiency and nutrient absorption, especially in feedlot lambs, is imperative to promote better animal growth and reduce production costs. Given its beneficial effects on growth and detoxification, and its immunostimulant properties, the supply of zeolite clinoptilolite is becoming more common in ruminant animal production (VALPOTIC *et al*., 2017). Deligiannis *et al*. (2005) studied the effects of supplementation with natural zeolite (clinoptilolite) on sheep growth and gastrointestinal nematode infections and found no significant differences between the carcasses of animals studied; however, these authors observed smaller counts of eggs per gram (EPG) in animals supplemented with zeolites. These results suggest that using this mineral may reduce gastrointestinal nematode infections in sheep, thus minimizing the need for anthelmintic drugs. There have been several studies conducted with ruminants, but a lack of reports focusing on small ruminants and the cost of zeolite as a dietary supplement for lambs. Therefore, further studies using small ruminants are required.

The main objective of this study was to evaluate the effect of dietary supplementation with Brazilian natural zeolite on gastrointestinal nematode infections, growth performance, and economic viability of male and female feedlot lambs.

MATERIAL AND METHODS

The Embrapa Pecuária Sudeste Ethics Committee for Animal Use approved the experiment (protocol no. 06/2011). The study was carried out in São Carlos, São Paulo State, Brazil (22°01′10″ S and 47°53′38″ W). Forty-eight Santa Inês sheep (*Ovis aries*) were used (24 females and 24 males). All animals were weaned at 90 days of age and had an EPG ≥ 2000, measured three times before the experiment at 7-day intervals (natural infection in the pasture). When the trial was initiated, the animals were 110 days old on average, and the average initial weight was 22.6 kg for female animals and 24.0 kg for males. All animals were evenly divided for the different levels of supplementation based on their weight, age, and EPG, to obtain a homogeneous group.

The lambs were not treated with anthelmintic drugs at the time of weaning or throughout the experiment. The only preventive treatment administered was a single dose of the *Clostridium* vaccine. They were placed in a covered shed, with two sheep per pen. The pens had concrete floors and peanut straw bedding. Animals were allowed seven days for acclimatization to the new environment before the beginning of the experiment, which lasted for 91 days between August and November (spring season).

The zeolite used in the experiment was collected in the North of Tocantins, in Parnaíba Basin (Bacia do Parnaíba) Brazil, and contained 470 g/kg zeolite stilbite (BERNARDI *et al*., 2013). The material was ground and concentrated, and zeolite was separated from the contaminants (quartz, iron oxides, and hydroxides) through gravity concentration using a Humphrey spiral, yielding a zeolite stilbite concentration of 650 g/kg.

Four levels of supplementation were assigned as described by Esteves *et al*. (2017): 0, 25, 50, and 75 g zeolite per day, representing 0, 2.5, 5.0, and 7.5% of dry matter. The animals were randomly separated into groups, with four treatments and six replicates per sex in a randomized block design.

The experimental diet was designed for gains of up to 200 g/day (TECHNICAL COMMITTEE ON RESPONSES TO NUTRIENTS GREAT BRITAIN, 1993). The feed was provided *ad libitum* with a proportion of dry matter forage to concentrate of 40:60. It comprised sugarcane (40%), ground corn (45%), soybean meal (14%), urea (1%), mineral salt (0.5%), and calcitic limestone (0.1%). Sugarcane was cut into pieces of 0.01–0.03 m. The composition of mineral salts (nutrients/kg product) was as follows: calcium, 150 g; phosphorus, 80 g; magnesium, 10 g mg; copper, 500 mg; iron, 2,200 mg; cobalt, 40 mg; manganese, 2,000 mg; zinc, 2,500 mg; iodine, 50 mg; selenium, 14 mg; sulfur, 35 g; sodium, 120 g; and fluorine, 800 mg.

The experimental diets contained 14.8% crude protein, 28.7% neutral detergent fiber, 74% total digestible nutrients, 0.35% calcium, and 0.20% phosphorus, according to the analytical methods described by Nogueira *et al*. (2005). Diets were supplied twice daily at 8 AM and 4 PM, and mineral salts and water were provided *ad libitum*. The diets were weighed daily, the feeder was cleaned, and the leftovers from the previous supply were removed. The feed intake was adjusted to keep the leftovers in 5% of the total offered per day.

The animals were weighed to determine the total live weight gain and daily average weight gain every 14 days in the morning after 14 h of fasting. Male animals that reached an average live weight of 34 kg were taken to a specialized abattoir where they were stunned and slaughtered following humane slaughter practices. After evisceration, the carcasses were weighed and sent to a cold room where they were cooled to 4 °C and stored for 24 h before calculating the commercial carcass yield.

Fecal samples were directly obtained weekly from the rectum using plastic bags and used to perform counts of eggs per gram (EPG) (UENO; GONÇALVES, 1998). In addition, stool cultures were prepared every 14 days to determine the predominant genera of endoparasites. The infecting larvae were identified according to the following criteria: worm size, presence and size of the tail sheath, shape of the anterior region, space between the tip of the larva's tail and the tip of the sheath's tail, number and types of intestinal cells, and intensity of lugol coloration. One hundred larvae were counted, and the results were expressed as percentages for the genera found in the cultures (ROBERTS; O'SULLIVAN, 1950).

On the 28 th day after the beginning of the experiment and every 28 days following, blood samples were collected from the jugular vein into vacuum tubes containing EDTA sodium to determine packed cell volume (PCV), and into vacuum tubes without anticoagulant to evaluate total serum protein (TSP). PCV analysis was performed using the microhematocrit method, which is an indicator of animal health (HERNANDEZ; SÁNCHEZ; ROMERO, 2020). TSP was determined by the colorimetric method using a Bioclin kit. The readings were based on the reaction between peptide bonds and the cupric ion in an alkaline medium, resulting in a violet-colored complex with an intensity that is proportional to the total protein concentration of the sample. The readings were performed using a spectrophotometer with a 540 nm filter (GORNALL; BARDAWILL; DAVID, 1949).

The economic viability analysis of the experimental diets was based on the feedlot period. The parameters evaluated were: i) gross revenue or gross income, the sum of all money generated by the business, ii) variable costs (i.e., the expenses that vary in proportion to the volume of product produced by the business); iii) gross margin, defined as gross revenue less variable costs; and iv) profit, the difference between the amount earned and the amount spent on production. The variable costs included the acquisition of live animals (USD 2.18/kg), sugar cane, concentrate, salt (USD 0.127/kg of food consumed), *Clostridium* vaccination (USD 0.18/animal), machine cost per hour, and the cost of labor. Zeolite prices were established at the international price of USD 50/ton (FLANAGAN, 2020). As the fixed costs for all treatments were identical, only variable costs were considered. The gross revenue was determined from the sale of sheep for slaughter at the market value of USD 2.64/kg live weight.

Statistical analysis using the SAS statistical program (SAS INSTITUTE, 2003) was performed in two steps. The first analyzed the lamb's health assessment (EPG, PCV, and TSP), and the second examined the animal's performance (carcass yield and economic parameters). In the first step, the EPG count data were transformed to log10 (n+1), where n is the number of EPG in the feces. These data and the datasets related to PCV and TSP were analyzed using the MIXED procedure (SAS INSTITUTE, 2003). The fixed effects included in the model were treatment, sex, collection date, and the interactions among them ($Y = \mu + block + treatment + sex + treatment*sex + error_1 + date + date*treatment + date*sex + date*treatment*sex + error_2$). In the second step, the data on carcass yield and the calculated economic parameters were subjected to a variance analysis using the general linear model (GLM) procedure by considering the effects of the block, sex (male, female), and treatment ($Y= \mu + block + treatment + sex + treatment*sex + error$). For multiple comparisons of averages, the *t*-test with 5% significance was used with the least-squares means (LSMEANS) option. The initial weight was used as a covariate in the carcass yield and economic analyses. The data were adjusted for 56 and 91 days of feeding to determine the slaughter weight and carcass yield of male animals.

RESULTS AND DISCUSSION

All the animals that received zeolite dietary supplementation accepted the feed, and no adverse reactions were observed during the entire experiment (ESTEVES *et al*., 2017). Previous research with 2% natural zeolite supplementation through dry matter for *ad libitum* intake also showed no adverse reactions in sheep (DELIGIANNIS *et al*., 2005).

A significant statistical interaction ($P < 0.001$) was found between the collection date, animal sex, and EPG. Females presented significantly lower levels of infection (Figure 1A) in terms of EPG. A gradual decrease was observed throughout the collection dates, causing statistical differences (Figure 2). The mean TSP and PCV values for each treatment group are shown in Table 1. The means and standard deviations for TSP did not significantly vary by sex, with 5.63 ± 0.066 and 5.60 ± 0.067 g/dL for female and male animals, respectively. In contrast, the average PCV values differed ($P < 0.05$) between female (31.83 ± 0.620) and male (28.88 ± 0.570) animals as well as between collection dates ($P < 0.001$).

Considering gastrointestinal nematode infections, the transformed means for EPG per treatment group and their standard errors were as follows: 3.080 ± 0.089, 3.050 ± 0.086, 2.979 ± 0.087, and 2.972 ± 0.088 for treatments 0, 25, 50, and 75 g per animal per day, respectively. There was no interaction ($P > 0.05$) between levels of supplementation and EPG, although EPG counts were lower in the groups supplemented with dietary zeolite than those with no additive (Figure 1B).

On average, the coprocultures revealed that 75.7% of the nematodes parasitizing the animals were *Haemonchus contortus*, 22% were *Trichostrongylus* sp. and 2.3% *Cooperia* sp., for all animals considered together. In all experimental groups, *Haemonchus contortus* predominated. However, the animals showed no clinical signs associated with nematode infections and maintained normal PCV levels. There was no interaction ($P > 0.05$) among the levels of supplementation and EPG counts (Table 2).

Figure 2 shows that there was a significant decline in the EPG (transformed means) after two weeks of consumption with the experimental diet. The diet's efficacy in reducing the total average EPG from the first day of the experiment was 58% on the 14th day and gradually increased, reaching 97% on the 84th day. There was no need for anthelmintic treatment for any animal during the experimental period, representing 100% savings in chemical costs.

These findings differ from those of Deligiannis *et al.* (2005) on native Karagouniko sheep, where significantly lower ($P < 0.001$) EPG counts were

Figure 1 - Transformed means of egg per gram (EPG) in feces of male and female sheep (A) and the average of both sex (B) fed with zeolite supplementation (g per animal per day)

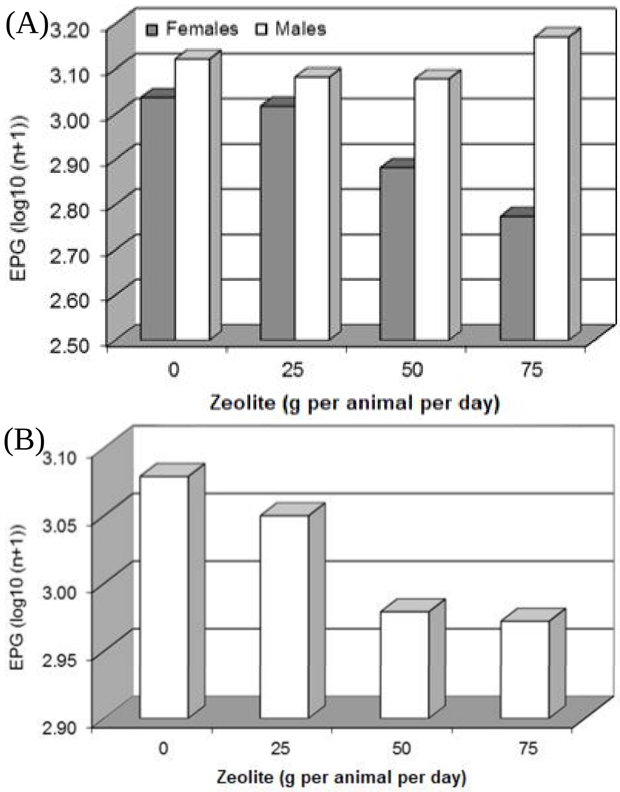

Figure 2 - Variation of transformed means of egg per gram (EPG) in lambs fed with zeolite supplementation (g per animal per day)

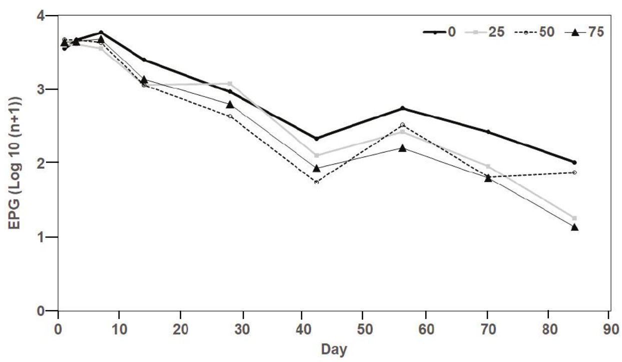

Table 1 - Means and standard deviations of packed cell volume (PCV) and total serum protein (TSP) levels for male and female lambs fed with dietary zeolite supplementation

Variables	Zeolite supplementation (g per animal per day)			
	0	25	50	75
PCV (%)	29.97 ± 0.89	29.83 ± 0.85	30.91 ± 0.86	30.72 ± 0.87
TSP (g/dL^{-1})	5.63 ± 0.096	5.52 ± 0.092	5.75 ± 0.093	5.58 ± 0.093

observed in animals receiving dietary supplementation with 3% clinoptilolite, another natural zeolite. However, those authors worked with artificial infections at a single dose and maintained the animals in individual stalls. Furthermore, clinoptilolite has a higher surface area, average diameter, pore volume, and cation exchange capacity than stilbite (BERNARDI *et al*., 2013). These characteristics make clinoptilolite more efficient, thereby supporting the effects described in the literature (DELIGIANNIS *et al*., 2005, PAPAIOANNOU *et al*., 2005) and explaining the comparatively lower efficiency of treatments observed in this study.

A factor that contributed to the smaller PCV values in male animals was their higher average EPG count than females. The stool cultures showed that 90% of the parasitic nematodes were *H. contortus,* and 10% were *Trichostrongylus* spp. at all levels of supplementation. The occurrence of the combined infection with these two species of nematodes has been described in studies conducted in other regions in the state of São Paulo (AMARANTE *et al*., 2004). As the severity of the infection strongly influences the averages for PCV with *H. contortus (*AMARANTE *et al.*, 2004) and since higher EPG counts were observed in male animals, it was expected that they would present lower PCV averages than female lambs.

The performance of the animals after 91 days of feeding was not influenced (P > 0.05) by the level of dietary zeolite supplementation (Table 3). The overall mean weight gain was 125 g/day. This value was lower than the 314 g/day reported in the study by Deligiannis *et al*. (2005) with infected and non-infected sheep fed a diet containing 3% clinoptilolite (the basal control diet).

McCollum and Galyean (1983) failed to observe any significant improvement in the daily average weight gain in bovines supplemented with up to 2.5% zeolite in the feed dry matter. In other studies involving sheep of the Santa Inês breed fed various forages, Murta *et al.* (2011) and Pereira *et al.* (2013) reported weight gains of more than 200 g/day.

The reduced animal performance observed in this study can be associated with food or diet constitution characteristics because the forage used was sugarcane, which has a low fiber digestion rate (CRUZ *et al.*, 2020). Mean weight gain was influenced by sex, as male animals gained weight at a significantly (P > 0.05) higher rate than females (140 g/day versus 111 g/day).

In the economic evaluation of the experimental diets, the use of zeolite did not influence the treatments, and except for gross revenue, all other studied variables were significantly (P < 0.05) influenced by sex (Table 4). Gross revenue did not vary (P > 0.05) among treatments because the final live weight was similar among treatments and averaged 33.0 kg.

Variable costs consisted of animal acquisition (59% of variable costs), feed (24%), and labor (17%) were similar among treatments, with significantly (P < 0.05) higher values for female animals than for males (USD 81.50 versus USD 76.59). The gross margin and consequently the profit (14.4% versus 7.9%) were significantly (P < 0.05) higher for male lambs than for females (USD 10.91 versus USD 6.46).

The kilograms of live weight were obtained from the division of each treatment’s variable costs by its respective live weight, and no significant (P > 0.05) differences were indicated among treatments. The average value was USD 2.38/kg of live weight. Live weight was significantly (P < 0.05) influenced by animal sex, with USD 2.31 for male animals and USD 2.46 for females (Table 4).

The lambs that reached the recommended average slaughter weight of 33 kg at 56 days of feeding presented significantly (P < 0.05) lower variable costs, and therefore higher gross margin and profit than those that reached the same weight after 91 days of feeding (Table 5).

The feeding period (56 or 91 days) significantly influenced the economic variables owing to higher labor expenses, and average feeding costs, causing significantly (P < 0.05) higher variable costs (USD 69.84 after 56 days versus USD 85.34 after 91 days). The higher variable costs also significantly (P < 0.05) and inversely affected the gross margin and profit. The average price of a kilogram of live weight produced for animals slaughtered at 56 days was significantly (P < 0.05) lower than that for animals slaughtered at 91 days (USD 2.10 and 2.47/kg live weight, respectively; Table 5).

Table 2 - Mean of nematode species from coprocultures (%) in male and female lambs fed with dietary zeolite supplementation

Nematode	Zeolite supplementation (g per animal per day)				Total
	0	25	50	75	
			%		
Haemonchus contortus	74.6	66.4	80.2	81.6	75.7
Trichostrongylus sp.	23.4	29.6	19.2	15.8	22.0
Cooperia sp.	2.0	4.0	0.6	2.6	2.3

Table 3 - Initial weight, final weight, and daily average weight gain for male and female animals fed with dietary zeolite supplementation

Variables	Zeolite supplementation (g per animal per day)				
	0 (control)	25	50	75	Average[1]
			Initial weight (kg)		
Males	22.5 ± 1.20	23.0 ± 1.20	24.4 ± 1.20	26.2 ± 1.20	24.0 ± 0.60
Females	22.9 ± 1.31	21.9 ± 1.20	23.0 ± 1.20	22.8 ± 1.20	22.6 ± 0.61
Average	22.7 ± 0.89	22.5 ± 0.85	23.7 ± 0.85	24.5 ± 0.85	23.3 ± 0.44
			Final weight (kg)		
Males	33.4 ± 0.94	33.2 ± 0.86	32.8 ± 0.87	33.3 ± 0.92	33.2 ± 0.44
Females	34.1 ± 0.87	32.9 ± 0.88	32.1 ± 0.86	34.2 ± 0.86	33.3 ± 0.45
Average	33.7 ± 0.64	33.0 ± 0.62	32.4 ± 0.61	33.8 ± 0.62	33.2 ± 0.49
			Daily average weight gain (g per animal per day)		
Males	0.122 ± 0.014	0.132 ± 0.013	0.143±0.013	0.162 ± 0.013	0.140 ± 0.007A
Females	0.119 ± 0.014	0.106 ± 0.013	0.097±0.013	0.120 ± 0.013	0.111 ± 0.007B
Average	0.123 ± 0.008	0.121 ± 0.008	0.127±0.009	0.136 ± 0.011	0.125 ± 0.01

[1] Different letters in the same column indicate statistical differences, *t*-test ($P < 0.05$)

Table 4 - Economic viability analysis (USD) of confined male and female sheep fed with dietary zeolite supplementation

Variables	Zeolite supplementation (g per animal per day)				
	0 (control)	25	50	75	Average[1]
			Gross Revenue		
Males	88.06 ± 2.28	87.59 ± 2.27	86.45 ± 2.29	87.9 ± 2.43	87.5 ± 1.15
Females	90.04 ± 2.49	86.74 ± 2.31	84.72 ± 2.27	90.32 ± 2.28	87.95 ± 1.18
Average	89.05 ± 1.69	87.16 ± 1.63	85.59 ± 1.61	89.11 ± 1.64	87.68 ± 5.56
			Variable Costs		
Males	80.07 ± 1.74	77.22 ± 1.73	74.31 ± 1.75	74.74 ± 1.85	76.59 ± 0.88 A
Females	82.73 ± 1.90	80.88 ± 1.76	80.69 ± 1.74	81.69 ± 1.74	81.5 ± 0.90 B
Average	81.40 ± 1.29	79.06 ± 1.24	77.5 ± 1.23	78.21 ± 1.25	78.96 ± 4.24
			Gross Margin		
Males	7.99 ± 2.61	10.37 ± 2.59	12.14 ± 2.62	13.16 ± 2.77	10.91 ± 1.31 A
Females	7.30 ± 2.84	5.86 ± 2.63	4.03 ± 2.59	8.64 ± 2.60	6.46 ± 1.35 B
Average	7.65 ± 1.93	8.11 ± 1.86	8.08 ± 1.83	10.9 ± 1.88	8.71 ± 6.34
			Profit (%)		
Males	4.86 ± 1.62	6.3 ± 1.62	7.64 ± 1.67	7.87 ± 1.76	6.67 ± 0.83 A
Females	4.07 ± 1.81	3.36 ± 1.67	2.31 ± 1.62	4.91 ± 1.62	3.66 ± 0.83 B
Average	4.44 ± 1.20	4.81 ± 1.16	4.95 ± 1.16	6.39 ± 1.16	5.19 ± 3.98
			USD/kg of live weight		
Males	2.41 ± 0.07	2.36 ± 0.07	2.2 ± 0.07	2.26 ± 0.08	2.31 ± 0.04 B
Females	2,44 ± 0.08	2.48 ± 0.07	2.53 ± 0.07	2.4 ± 0.07	2.46 ± 0.04 A
Average	2.42 ± 0.06	2.42 ± 0.05	2.36 ± 0.05	2.33 ± 0.05	2.38 ± 0.18
Carcass yield (%)	20.58 ± 0.30	20.0 ± 0.29	20.34 ± 0.29	20.08 ± 0.31	20.25 ± 0.65
USD/kg of carcass	5.49 ± 0.22	5.43 ± 0.22	4.95 ± 0.22	5.04 ± 0.23	5.23 ± 0.53

[1] Different letters in the same column indicate statistical differences, *t*-test ($P < 0.05$)

Table 5 - Economic viability analysis (USD) of male lambs slaughtered after 56 or 91 days with dietary zeolite supplementation

Variable	0 (control)	25	50	75	Average[1]
	g per animal per day				
	Gross revenue (USD)				
Males (56 days)	88.86 ± 5.69	90.70 ± 4.58	87.05 ± 3.15	89.12 ± 3.43	88.94 ± 2.41
Males (91 days)	89.94 ± 2.82	88.55 ± 3.56	90.08 ± 4.44	90.96 ± 6.25	89.88 ± 2.76
	Variable Costs (USD)				
Males (56 days)	70.36 ± 1.33	68.92 ± 1.06	69.60 ± 0.73	70.49 ± 0.79	69.84 ± 0.56 B
Males (91 days)	85.06 ± 0.65	84.40 ± 0.82	85.10 ± 1.03	86.79 ± 1.44	85.34 ± 0.65 A
	Gross Margin (USD)				
Males (56 days)	18.52 ± 4.98	21.78 ± 3.98	17.45 ± 2.73	18.63 ± 2.96	19.09 ± 2.09 A
Males (91 days)	4.88 ± 2.44	4.15 ± 3.09	4.98 ± 3.86	4.18 ± 5.43	4.55 ± 2.40 B
	Profit (%)				
Males (56 days)	12.27 ± 2.99	14.39 ± 2.38	11.41 ± 1.63	11.84 ± 1.77	12.48 ± 1.25 A
Males (91 days)	2.35 ± 1.46	1.54 ± 1.85	2.22 ± 2.31	1.50 ± 3.25	1.90 ± 1.44 B
	USD/kg of live weight				
Males (56 days)	2.08 ± 0.15	2.05 ± 0.11	2.13 ± 0.07	2.13 ± 0.07	2.10 ± 0.05 B
Males (91 days)	2.47 ± 0.05	2.52 ± 0.05	2.46 ± 0.06	2.43 ± 0.06	2.47 ± 0.03 A
	USD/kg of carcass				
Males (56 days)	4.70 ± 0.52	5.48 ± 0.37	4.81 ± 0.28	5.16 ± 0.23	5.04 ± 0.18
Males (91 days)	5.60 ± 0.23	5.38 ± 0.28	5.27 ± 0.37	4.72 ± 0.52	5.24 ± 0.18

[1] Different letters in the same column indicate statistical differences, *t*-test, $P < 0.05$

The addition of zeolite to the sheep feed did not produce any significant ($P > 0.05$) effect on cold carcass yield (average 43.7%), regardless of treatment group or feedlot time (56 or 91 days, Table 5). Fernandes *et al*. (2011) reported variation in carcass yield from 40% to 50% in sheep of the Santa Inês breed, with average slaughter weights similar to those adopted in this study. However, Deligiannis *et al.* (2005) stated that the inclusion of zeolite in the diet did not improve carcass yield.

CONCLUSIONS

1. Zeolite was not an efficient dietary supplement for avoiding gastrointestinal nematode infection or improving the growth performance of male and female Santa Ines lambs;
2. Male animals exhibited superior performance and better economic results than female animals in the feedlot. Increasing the feeding period decreased profitability from 12.5% to 1.9% since male animals slaughtered earlier (at 56 days) were more economically viable than those slaughtered later (at 91 days).

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