Pesquisa Agropecuária Brasileira

ISSN 1678-3921

Journal homepage: www.embrapa.br/pab

For manuscript submission and journal contents, access: www.scielo.br/pab

Mariana Dalla Favera Almeida de Oliveira (✉)
Universidade Federal de Santa Maria, Santa Maria, RS, Brazil.
E-mail: marianadallaf@gmail.com

Sérgio Carvalho
Universidade Federal de Santa Maria, Santa Maria, RS, Brazil.
E-mail: scarvalhoufsm@hotmail.com

Viviana Reboledo da Costa
Universidade Federal de Santa Maria, Santa Maria, RS, Brazil.
E-mail: vivianazoot@gmail.com

Bernardo da Trindade Gallaretta
Universidade Federal de Santa Maria, Santa Maria, RS, Brazil.
E-mail: begallarreta@hotmail.com

Greicy Sofia Maysonnave
Seta S.A., Estância Velha, RS, Brazil.
E-mail: greicysm@gmail.com

Gabriela Pires Scherer
Seta S.A., Estância Velha, RS, Brazil.
E-mail: gabrielapiresscherer@gmail.com

Danielle Dias Brutti
Seta S.A., Estância Velha, RS, Brazil.
E-mail: danielle.brutti@setaoficial.com

Daniel Uliana
Universidade Federal de Santa Maria, Santa Maria, RS, Brazil.
E-mail: danielvedovatouliana@gmail.com

Pedro Henrique Galvão
Universidade Federal de Santa Maria, Santa Maria, RS, Brazil.
E-mail: galvao.pedrohenrique@gmail.com

Diúlia Zolin Galvani
Universidade Federal de Santa Maria, Santa Maria, RS, Brazil.
E-mail: diulia.zootecnia@gmail.com

Camila Milani de Moraes
Universidade Federal de Santa Maria, Santa Maria, RS, Brazil.
E-mail: camilanimoraes@gmail.com

✉ Corresponding author

Received
January 15, 2025

Accepted
May 29, 2025

How to cite
OLIVEIRA, M.D.F.A. de; CARVALHO, S.; COSTA, V.R. da; GALLARETTA, B. da T.; MAYSONNAVE, G.S.; SCHERER, G.P.; BRUTTI, D.D.; ULIANA, D.; GALVÃO, P.H.; GALVANI, D.Z.; MORAES, C.M. de. Zootechnical performance of lambs fed different levels of black wattle tanin extract. **Pesquisa Agropecuária Brasileira**, v.60, e04013, 2025. DOI: https://doi.org/10.1590/S1678-3921.pab2025.v60.04013.

Animal Science/ Original Article

Zootechnical performance of lambs fed different levels of black wattle tanin extract

Abstract – The objective of this work was to evaluate the effect of different levels of black wattle tannin extract on the intake, performance, and carcass characteristics of lambs in confinement. Forty uncastrated, 50-day-old, Texel x Ile de France male lambs were used. The treatments consisted of the following five levels of added tannin extract (percentage of total dry matter in the diet): 0 (control), 1.0, 2.0, 3.0, and 4.0%. A quadratic effect was observed for the intake of dry matter, organic matter, crude protein, ether extract, neutral detergent fiber, total carbohydrates, non-structural carbohydrates, and total digestible nutrients, as well as for average daily weight gain, whose maximum value was 0.303 kg at the level of 1.6% tannin extract. There was also a quadratic effect for hot and cold carcass yields, subcutaneous fat thickness, fat content, and carcass conformation. The level of 1.6% black wattle tannin extract is recommended to be added to the total dry matter of the diet of lambs in confinement due to the obtained highest weight gains, higher dry matter and nutrient intake, and greater average daily gain, which improve the body condition score and conformation at slaughter of the animals.

Index terms: *Ovis aries*, confinement, polyphenols, weight gain.

Desempenho zootécnico de cordeiros alimentados com diferentes níveis de extrato de tanino de acácia-negra

Resumo – O objetivo deste trabalho foi avaliar o efeito de diferentes níveis de extrato de tanino de acácia-negra sobre o consumo, o desempenho e as características de carcaça de cordeiros confinados. Foram utilizados 40 cordeiros machos Texel x Ile de France, não castrados, com 50 dias de idade. Os tratamentos consistiram nos seguintes cinco níveis de inclusão de extrato de tanino (percentagem da matéria seca total da dieta): 0 (controle), 1,0, 2,0, 3,0 e 4,0%. Observou-se efeito quadrático sobre os consumos de matéria seca, matéria orgânica, proteína bruta, extrato etéreo, fibra em detergente neutro, carboidratos totais, carboidratos não estruturais e nutrientes digestíveis totais, bem como sobre ganho de peso médio diário, cujo ponto máximo foi de 0,303 kg no nível de 1,6% de extrato de tanino. Também houve efeito quadrático sobre os rendimentos de carcaça quente e fria, a espessura de gordura subcutânea, o estado de engorduramento e a conformação das carcaças. Recomenda-se a adição de 1,6% de extrato de tanino de acácia-negra na matéria seca total da dieta de cordeiros confinados devido aos melhores ganhos de peso, ingestão de matéria seca e de nutrientes, e ganho médio de peso obtidos, o que melhora o escore de condição corporal e a conformação no abate dos animais.

Termos para indexação: *Ovis aries*, confinamento, polifenóis, ganho de peso.

Introduction

Sheep farming for meat production has been expanding in Brazil in recent years, influenced by the steadily growing market for lamb and mutton (Costa et al., 2024). To meet market demands, sheep producers have sought to improve production techniques, focusing on meat quality and on increasing productivity. Sheep confinement is considered an alternative for intensifying production and making the production system more efficient during the finishing phase of the animals (Souza et al., 2014).

In sheep confinement, feed intake is a crucial factor since an adequate nutrition is essential for a good animal performance and development. In this context, the use of tannins in sheep diets is an interesting alternative due to the potential improvements in animal performance (Orlandi et al., 2020a). According to Vieira et al. (2020), tannins are phenolic compounds found in plants that show the ability to form complexes with proteins and carbohydrates and reduce rumen degradation. Based on this, earlier studies have shown that tannins can improve nitrogen use by ruminants, as well as feed conversion and animal performance (Orlandi et al., 2020b). However, when used at high doses, tannins cause a repulsive odor and astringency, considered anti-nutritional factors that lead to a reduced palatability (Costa et al., 2021a), which alters the animal's ingestive behavior and, consequently, reduces feed consumption.

Besharati et al. (2022), in a review on the use of tannins in ruminant feed, concluded that the addition of high levels in the dry matter of the animal diet can lead to adverse effects related to a reduced feed intake and consequent lower weight gain. In this line, Costa et al. (2021a) stated that, as the levels of tannins (0, 20, 40, 60, and 80 g total carbohydrates per kilogram of dry matter) in the diet increased, there was a reduction in the carcass characteristics of sheep in confinement. Therefore, at high percentages in the diet, tannins may become toxic and affect animal performance.

In the literature, there have also been reports of positive effects of the addition of tannin extract in animal diets depending on the used doses. Chiaia et al. (2016), for example, tested the use of different levels of tannins and reported a better feed conversion for animals fed a diet containing 1.5% tannins (percentage of dry matter) than only 0.2%, a result attributed to the increased availability of dietary protein to be absorbed at the intestinal level. Lima et al. (2019) observed that black wattle (*Acacia mearnsii* De Wild.) tannin extract at a dose of 30 g kg^{-1} affected the ingestive behavior of sheep, increasing total feeding time.

The objective of this work was to evaluate the effect of different levels of black wattle tannin extract on the intake, performance, and carcass characteristics of lambs in confinement.

Materials and Methods

The experiment was carried out at Universidade Federal de Santa Maria, located in the municipality of Santa Maria, in the state of Rio Grande do Sul, Brazil (29º43'S, 53º42'W, at an altitude of 95m). The climate is of the Cfa type, humid subtropical, according to Köppen's classification. Forty uncastrated Texel x Ile de France crossbred male lambs were used, weaned at 50 days of age and properly dewormed and vaccinated against clostridiosis. The animals were confined in individual and fully-covered pens (2.0 m^2 per animal) with slatted floors approximately 1.0 m above the ground. Each pen was equipped with an individual feeder and water trough.

The animals were distributed in a completely randomized experimental design of five treatments, each with eight replicates. The treatments consisted of different levels of black wattle tannin extract added to the diet, as follows: 0 (control), 1.0, 2.0, 3.0, and 4.0% of total dry matter.

The experimental period included 10 days for adaption to the facilities, feed, and handling. The lambs were weighed at the start of the experimental phase and then every 14 days to monitor their performance, always after fasting for 14 hours. The animals were slaughtered after a fixed period of 60 days.

The total diet was offered ad libitum and consisted of maize silage as bulk and a concentrate comprising crushed maize, soybean meal, calcitic limestone, and common salt, with different doses of black wattle tannin extract added according to each treatment. A bulk-to-concentrate ratio of 45:55, on a dry matter basis, was used. The diets were formulated to be isoproteic as described by National Research Council (NRC, 2007) and calculated to meet the requirements of the category (Table 1).

During the experiment, the animals were fed daily in the morning (8:30 a.m.) and in the afternoon

(5:30 p.m.), allowing for approximately 15% of the feed to be left over per day to ensure maximum voluntary consumption. Samples of the leftovers and feed were collected every 7 days and formed into composite samples, which were packed in plastic bags, identified, and stored in a freezer, at -20°C, for later laboratory analysis.

For the bromatological analysis, the food samples and leftovers were pre-dried in a forced-air oven, at 55°C, for approximately 72 hours, then ground in a Willey mill with a 1.0 mm sieve, packed in bottles, and labelled.

The dry matter content of the feed and leftovers was determined by oven drying, at 105°C, for at least 16 hours, being expressed in kilograms per day, percentage of live weight (LW), and g kg^{-1} $LW^{0.75}$ (Tables 2, 3, and 4, respectively). Ash content was obtained by combustion, at 600°C, for 4 hours (Silva & Queiroz, 2002). The levels of total nitrogen were determined by the Kjeldahl method, following method 984.13 of Association of Official Analytical Chemists (AOAC) (Cunniff, 1997). The levels of ether extract were obtained according to Silva & Queiroz (2002). To determine the concentration of neutral detergent fiber, the samples were placed in polyester bags and treated with a neutral detergent solution in an autoclave, at 110°C, for 40 min; a-amylase was used for the samples of concentrate. Acid detergent fiber was obtained using method 973.18 of AOAC (Cunniff, 1997). Total carbohydrates were determined as described in Sniffen et al. (1992), using the equation: total carbohydrates (%) = 100 - (% crude protein + % ether extract + % ash content).

The difference between the amount of feed offered and the leftovers (on a dry matter basis) was used to calculate the daily intake of dry matter, organic matter, crude protein, ether extract, neutral detergent fiber, acid detergent fiber, total carbohydrates, non-structural carbohydrates, and total digestible nutrients.

Once the lambs had completed the 60 day experimental period, they were handcuffed to obtain their farm live weight. Then, they were fasted for 14 hours and weighed again to determine their slaughter live weight. Fasting losses were obtained from the

Table 1. Percentage of ingredients and chemical composition of the experimental diets fed to lambs in confinement.

Variable	Level of tannin extract (percentage of dry matter)				
	0	1	2	3	4
Percentage of ingredient (g kg^{-1})					
Maize silage	450.00	450.00	450.00	450.00	450.00
Crushed maize	217.70	205.90	193.80	181.90	169.80
Soybean meal	311.10	313.10	315.20	317.30	319.40
Tannin extract	0.00	10.00	20.00	30.00	40.00
Calcitic limestone	11.20	11.00	11.00	10.80	10.80
Common salt	10.00	10.00	10.00	10.00	10.00
Bromatological composition(1)					
DM (g kg^{-1})	608.50	608.70	608.90	609.00	609.20
OM (g kg^{-1} DM)	926.90	917.20	907.40	897.70	887.90
CP (g kg^{-1} DM)	188.10	188.10	188.10	188.10	188.10
EE (g kg^{-1} DM)	22.10	21.90	21.70	21.50	21.20
NDF (g kg^{-1} DM)	308.20	307.20	306.20	305.20	304.20
ADF (g kg^{-1} DM)	153.40	153.20	153.00	152.80	152.60
TCH (g kg^{-1} DM)	724.70	724.60	724.30	724.10	723.80
NSC (g kg^{-1} DM)	416.50	417.30	418.10	418.90	419.60
TDN (g kg^{-1} DM)	701.10	692.50	683.70	674.90	666.10
Ash (g kg^{-1} DM)	65.10	65.20	65.50	65.70	66.00
Ca (g kg^{-1} DM)	6.20	6.20	6.20	6.20	6.20
P (g kg^{-1} DM)	3.10	3.10	3.10	3.10	3.10

(1)DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber; TCH, total carbohydrates; NSC, non-structural carbohydrates; TDN, total digestible nutrients; Ca, calcium; and P, phosphorus.

DOI: 10.1590/S1678-3921.pab2025.v60.04013

Table 2. Average intake of dry matter (DMI), organic matter (OMI), crude protein (CPI), ether extract (EEI), neutral detergent fiber (NDFI), acid detergent fiber (ADFI), total carbohydrates (TCHI), non-structural carbohydrates (NSCI), and total digestible nutrients (TDNI), expressed in kilograms per day, by lambs fed different levels of black wattle (*Acacia mearnsii*) tannin extract in their diet.

Variable	Level of tannin extract (% of dry matter)					Regression(1)	CV(2) (%)	p>F(3)
	0	1	2	3	4			
DMI	1.416	1.596	1.615	1.500	1.229	$\bar{Y}$=1.41680+0.25005TAN-0.07425TAN². R^2 = 0.16	22.15	0.0352
OMI	1.311	1.460	1.461	1.329	1.079	$\bar{Y}$=1.31362+0.20733TAN-0.06670TAN². R^2 = 0.19	22.15	0.0188
CPI	0.276	0.311	0.314	0.294	0.244	$\bar{Y}$=0.27650+0.04728TAN-0.01385TAN². R^2 = 0.15	22.13	0.0271
EEI	0.040	0.044	0.045	0.042	0.033	$\bar{Y}$=0.03991+0.00693TAN-0.00214TAN². R^2 = 0.19	21.91	0.0195
NDFI	0.404	0.456	0.456	0.423	0.349	$\bar{Y}$=0.40567+0.06740TAN-0.02046TAN². R^2 = 0.16	22.51	0.0396
ADFI	0.213	0.226	0.227	0.210	0.175	$\hat{Y}$=0.210	22.42	0.0585
TCHI	1.009	1.137	1.150	1.061	0.869	$\bar{Y}$=1.01013+0.17714TAN-0.05320TAN². R^2 = 0.17	22.22	0.0313
NSCI	0.602	0.680	0.690	0.640	0.523	$\bar{Y}$=0.60267+0.10895TAN-0.03222TAN². R^2 = 0.17	21.99	0.0311
TDNI	0.992	1.106	1.104	1.012	0.818	$\bar{Y}$=0.99410+0.15764TAN-0.05044TAN². R^2 = 0.19	22.12	0.0199

(1)TAN, level of black wattle tannin extract in the diet. (2)Coefficient of variation. (3)p≤0.05.

Table 3. Average intake of dry matter (DMI), organic matter (OMI), crude protein (CPI), ether extract (EEI), neutral detergent fibre (NDFI), acid detergent fibre (ADFI), total carbohydrates (TCHI), non-structural carbohydrates (NSCI), and total digestible nutrients (TDNI), expressed as percentage of live weight, by lambs fed different levels of black wattle (*Acacia mearnsii*) tannin extract in their diet.

Variable	Level of tannin extract (% of dry matter)					Regression(1)	CV(2) (%)	p>F(3)
	0	1	2	3	4			
DMI	4.98	5.48	5.60	5.14	4.70	$\bar{Y}$=5.00399+0.61154TAN-0.17513TAN². R^2 = 0.28	10.29	0.0026
OMI	4.61	5.02	5.06	4.57	4.13	$\bar{Y}$=4.63684+0.49420TAN-0.15861TAN². R^2 = 0.34	10.24	0.0005
CPI	0.97	1.06	1.09	1.01	0.92	$\bar{Y}$=0.97829+0.11436TAN-0.03258TAN². R^2 = 0.24	10.55	0.0055
EEI	0.14	0.15	0.16	0.14	0.13	$\bar{Y}$=0.14097+0.01696TAN-0.00521TAN². R^2 = 0.33	10.52	0.0006
NDFI	1.43	1.58	1.59	1.46	1.34	$\bar{Y}$=1.44511+0.16138TAN-0.04819TAN². R^2 = 0.28	10.30	0.0024
ADFI	0.75	0.78	0.79	0.73	0.67	$\bar{Y}$=0.74974+0.04867TAN-0.01726TAN². R^2 = 0.24	10.08	0.0063
TCHI	3.54	3.91	3.98	3.65	3.32	$\bar{Y}$=3.56552+0.43711TAN-0.12665TAN². R^2 = 0.29	10.21	0.0017
NSCI	2.12	2.33	2.39	2.17	1.99	$\bar{Y}$=2.13557+0.25846TAN-0.07548TAN². R^2 = 0.26	11.03	0.0036
TDNI	3.49	3.79	3.83	3.47	3.13	$\bar{Y}$=3.50950+0.37371TAN-0.11942TAN². R^2 = 0.33	10.27	0.0006

(1)TAN, level of black wattle tannin extract in the diet. (2)Coefficient of variation. (3)p≤0.05.

Table 4. Average intake of dry matter (DMI), organic matter (OMI), crude protein (CPI), ether extract (EEI), neutral detergent fiber (NDFI), acid detergent fiber (ADFI), total carbohydrates (TCHI), non-structural carbohydrates (NSCI), and total digestible nutrients (TDNI), expressed in g kg^{-1} live $weight^{0.75}$, by lambs fed different levels of black wattle (*Acacia mearnsii*) tannin extract in their diet.

Variable	Level of tannin extract (percentage of dry matter)					Regression(1)	CV(2) (%)	p>F(3)
	0	1	2	3	4			
DMI	114.38	127.03	130.05	118.98	105.93	$\bar{Y}$=114.86930+16.15861TAN-4.66041TAN². R^2 = 0.34	10.30	0.0005
OMI	105.93	116.22	117.66	105.77	93.21	$\bar{Y}$=106.46335+13.21509TAN-4.19762TAN². R^2 = 0.39	10.25	<.0001
CPI	22.25	24.62	25.19	23.25	20.79	$\bar{Y}$=22.33465+3.03761TAN-0.86644TAN². R^2 = 0.24	10.23	0.0009
EEI	3.22	3.53	3.62	3.29	2.85	$\bar{Y}$=3.22719+0.44313TAN-0.13514TAN². R^2 = 0.40	10.17	<.0001
NDFI	32.59	36.65	36.42	33.78	30.22	$\bar{Y}$=32.89599+4.31827TAN-1.26783TAN². R^2 = 0.33	10.36	0.0007
ADFI	17.18	18.18	18.08	16.81	15.22	$\bar{Y}$=17.23905+1.28458TAN-0.45273TAN². R^2 = 0.28	10.19	0.0021
TCHI	81.55	90.44	92.54	84.51	75.07	$\bar{Y}$=81.89409+11.43348TAN-3.32872TAN². R^2 = 0.35	10.28	0.0004
NSCI	48.54	53.89	55.25	49.79	44.89	$\bar{Y}$=48.82856+6.63128TAN-1.94132TAN². R^2 = 0.31	11.02	0.0010
TDNI	80.19	87.97	88.92	80.30	70.56	$\bar{Y}$=80.57087+10.01402TAN-3.17448TAN². R^2 = 0.39	10.26	<.0001

(1)TAN, level of black wattle tannin extract in the diet. (2)Coefficient of variation. (3)p≤0.05.

difference between farm live weight and slaughter live weight. The body condition score was then evaluated together with in vivo conformation using a method adapted from Osório et al. (1998), consisting of assigning a value from 1 to 5, in increments of 0.25, where 1 is very poor and 5 is excellent. The animals were then stunned and slaughtered by bleeding.

After each slaughter, carcass was weighed to determine hot carcass weight. Hot carcass yield was obtained through the equation: HCY = (HCW/LWS) x 100, where HCY is hot carcass yield, HCW is hot carcass weight, and LWS is slaughter live weight. Each carcass was then chilled for 24 hours in a cold chamber, at 1°C, and weighed again to calculate cold carcass weight, cold carcass yield, and the chilling loss index. Cold carcass yield and the chilling loss index were obtained using the following equations: CCY = (CCW/LWS) x 100 and CLI = 100-((CCW/HCW) x 100), respectively, where CCY is cold carcass yield, CCW is cold carcass weight, LWS is slaughter live weight, CLI is the chilling loss index, and HCW is hot carcass weight. To show the development of the carcass, its fat content was evaluated subjectively by estimating the amount of fat distribution, using a range similar to that for carcass conformation, from 1 to 5, where 1 is excessively lean and 5 is excessively fat.

Each carcass was then immediately split longitudinally into two halves using an electric saw. To assess the left half of the carcass, measurements were taken of the length of the carcass, length of the leg, width of the leg, and depth of the chest according to Osório et al. (1998).

The *longissimus dorsi* muscle of the left half of the carcass was exposed through a transverse cut between the twelfth and thirteenth ribs in order to determine color, texture, and marbling. Color was assessed visually, by assigning scores on a scale from 1 to 5, in increments of 0.5, where 1 represents light pink and 5, dark red. Texture was evaluated by a subjective visual assessment of the size of the fiber bundles, assigned scores from 1 to 5, in increments of 0.5, where 1 is very coarse and 5 is very fine. Marbling was also determined by visual observation by classifying intramuscular fat on a scale from 1 to 5, where 1 is nonexistent and 5 is excessive (Osório et al., 1998). To obtain loin eye area, an outline of the muscle was drawn on tracing paper using the AutoCAD software (Autodesk, San Francisco, CA, USA) with a graphics tablet for the readings. Subcutaneous fat thickness was assessed in the same region and measured in millimeters, using a digital caliper.

After processing, the right half of the carcass was split into four commercial cuts: leg, shoulder, ribs, and neck according to Osório et al. (1998). The cuts were weighed separately to calculate their proportion of cold carcass weight.

The experimental design was completely randomized, with eight replicates used to evaluate the five treatments. After data collection, the results were subjected to the analysis of variance and regression analysis. The adopted equations were selected based on the coefficients of determination and the significance of the regression coefficients, using the t-test at a 5% significance level.

Results and Discussion

There was a quadratic effect of level of tannin in the diet on the intakes of dry matter, organic matter, crude protein, ether extract, neutral detergent fiber, total carbohydrates, non-structural carbohydrates, and total digestible nutrients. This means that nutrient intake tends to increase up to a maximum level and then to decrease. The maximum dry matter intake was 1.63 kg per day at 1.7% tannin addition to the total dry matter of the diet. However, the coefficient of determination of the equation was low due to the high coefficient of variation observed for the data.

An adequate dry matter intake is important for sheep performance, which is directly linked to the intake of nutrients from the diet. According to Costa et al. (2021b), feed intake is influenced by several factors, among which the fiber content of a diet stands out. In the present study, neutral detergent fiber reached values close to the 30% recommended in the literature (Kosloski et al., 2006) regardless of the used level of tannins (Table 1). Taking into account energy content, there was a small variation in the proportion of neutral detergent fiber in the bromatological composition of the diets, meaning that there was a small probability of differences in intake being caused by any physiological control of feeding. The levels of moisture and ether extract also varied little between diets and were at levels below those reported in the literature as having a negative effect on intake, i.e., 50% moisture and 5.0% ether extract (Grandis et al., 2015).

There was a reduction in intake at 1.7% tannins in the total dry matter of the diet, which can be attributed to a reduction in palatability due to the high levels of concentrated tannin that can reduce nutrient intake and digestibility, resulting in a reduced animal performance (Silva et al., 2016; Min & Solaiman, 2018). However, at moderate levels of tannin in the diet, i.e., below 1.7% of dry matter, there was an increase in the consumption and weight gain of the animals, representing the benefits of using adequate tannin levels.

In relation to crude protein intake, regardless of the level of tannin in the diet, all values were higher than that of 116 g crude protein per day recommended by NRC (2007) for late-maturing lambs with a live weight of 20 kg and daily gain of 200 g. The maximum crude protein intake estimated from the regression equation was 0.317 kg per day at a level of 1.7% tannin extract in the diet, in line with the result obtained for dry matter intake. Similarly, when evaluating the intake of total digestible nutrients, values higher than that of 0.39 kg per day recommended by the NRC were observed for all treatments. The maximum intake of total digestible nutrients was 1.117 kg per day at a tannin extract level of 1.6% of the total dry matter of the diet. These intake levels are important since they relate to nutrients that have a direct influence on animal performance, specifically on weight gain, degree of finishing, and carcass characteristics.

In the evaluation of the variables related to animal performance, the increase in tannin extract in the diet showed a quadratic effect on the average daily weight gain, in vivo conformation, and body condition score of the lambs at slaughter (Table 5). The maximum value for average daily weight gain was 0.306 kg per day, obtained at a level of 1.6% tannin extract in the diet. This result can be attributed to dry matter intake, which reached a maximum at 1.7% added tannins and determined the maximum intake of crude protein and total digestible nutrients at a level of 1.6 and 1.7% tannin extract in the diet, respectively.

According to Gemeda & Hassen (2015), tannins act as a nutrient modulator, leading to a reduction in the action of methanogenic bacteria in the rumen and, consequently, in methane production. This has two important implications for the use of tannins: an improvement in energy use due to a reduction in the energy lost in the form of methane, helping to improve animal productive performance; and a reduction in the production and emission of methane, an effective way of achieving a more sustainable animal production, a major environmental issue today. With a higher dry matter intake and a consequent higher nutrient intake, there was a greater average daily gain, resulting in animals with a better body condition score and better conformation at slaughter. The variables for initial live weigh, farm live weight, live weight at slaughter, fasting loss, and feed conversion were not significantly affected by the addition of tannin extract.

Table 5. Mean values for initial live weight (ILW), farm live weight (FLW), weight at slaughter after fasting (LWS), fasting loss (FL), average daily weight gain (ADG), feed conversion (FC), conformation, and body condition score (BCS) of lambs fed different levels of black wattle (*Acacia mearnsii*) tannin extract in their diet.

Zootechnical variable	Level of tannin extract (percentage of dry matter)					Regression(1)	CV(2) (%)	p>F(3)
	0	1	2	3	4			
ILW (kg)	21.21	21.00	21.91	21.46	21.01	$\hat{Y}$=21.33	22.61	0.9640
FLW (kg)	39.70	42.02	42.77	39.90	35.01	$\hat{Y}$=39.80	19.42	0.1915
LWS (kg)	37.45	39.03	39.89	37.56	32.70	$\hat{Y}$=37.18	19.60	0.2207
FL (kg)	2.66	2.98	2.88	2.34	2.31	$\hat{Y}$=2.63	34.39	0.1910
FL (%)	6.99	7.10	6.68	5.82	6.49	$\hat{Y}$=6.61	32.64	0.3528
ADG (kg per day)	0.271	0.301	0.303	0.268	0.200	$\bar{Y}=0.26166+0.05651TAN-0.01798TAN^2$ $R^2 = 0.38$	18.67	0.0002
FC	5.52	5.25	5.31	5.59	6.09	$\hat{Y}$=5.59	16.06	0.2505
Conformation (1–5)(4)	3.11	3.25	3.50	3.06	2.69	$\bar{Y}=3.04254+0.41433TAN-0.12702TAN^2$ $R^2 = 0.20$	16.68	0.0172
BCS (1–5)(4)	3.37	3.49	3.49	3.26	2.82	$\bar{Y}=3.34131+0.26375TAN-0.09781TAN^2$ $R^2 = 0.31$	11.73	0.0014

(1)TAN, level of black wattle tannin extract in the diet. (2)Coefficient of variation. (3)$p \leq 0.05$. (4)Scores on a visual scale from 1 to 5.

From the derived regression equation, a maximum conformation of 3.38 was obtained at the level of 1.6% tannin extract in the dry matter of the diet, which was in line with the results for the average daily gain and intake of the animals. The maximum body condition score, which is directly related to the degree of pre-slaughter finishing of the animal, was 3.52 at 1.3% tannin extract, being 3.51 at 1.6%. Therefore, it can be inferred that the degree of finishing was adequate since the value of 3.5 is considered acceptable for slaughter sheep by meat-packing plants and is classified as very good in the literature (Osório et al., 1998).

The different levels of tannin extract had a quadratic effect on hot carcass yield and cold carcass yield (Table 6), which showed maximum values of 49.29 and 47.76%, respectively, at 1.2 and 1.1% tannin extract in the total dry matter of the diet. This result can be explained by the quadratic variation observed in total gastrointestinal content.

According to the regression equation, the value for total gastrointestinal content decreased to 15.32% up to a tannin extract level of 1.1%, then started to increase. This finding is in line with the best results for carcass yield, considering the aforementioned values. Tannins, at moderate levels in the diet, can have a positive effect on the rumen degradation of dietary fiber, but, at high levels, can have a negative effect on fibrolytic bacteria and, consequently, on the degradation of the fibrous fraction of the feed (Besharati et al., 2022), increasing the gastrointestinal content of animals at slaughter.

The levels of tannin extract added to the diet also showed a quadratic effect on subcutaneous fat thickness, fat content, and conformation of the carcass. Subcutaneous fat thickness and fat content

Table 6. Mean values for lamb carcass characteristics and gastrointestinal content when fed different levels of black wattle (*Acacia mearnsii*) tannin extract in their diet(1).

Carcass characteristics	Level of tannin extract (percentage of dry matter)					Regression(2)	CV(3) (%)	p>F(4)
	0	1	2	3	4			
HCW (kg)	18.37	18.12	19.22	18.21	14.41	$\hat{Y}=5.59$	22.53	0.0822
CCW (kg)	17.88	17.59	18.66	17.50	13.98	$\hat{Y}=17.07$	22.60	0.0706
HCY (%)	48.70	48.69	48.10	48.45	43.74	$\hat{Y}=48.37376+1.51994TAN-0.63249TAN^2$. $R^2 = 0.38$	4.50	0.0002
CCY (%)	47.40	47.25	46.63	46.62	42.37	$\hat{Y}=47.12221+1.20202TAN-0.56622TAN^2$. $R^2 = 0.39$	5.07	0.0002
CLI (%)	2.67	2.97	3.06	3.71	3.12	$\hat{Y}=3.10$	43.61	0.2632
BCI (kg cm^{-1})	0.30	0.30	0.31	0.30	0.24	$\hat{Y}=0.29883+0.02515TAN-0.00934TAN^2$. $R^2 = 0.18$	17.86	0.0313
LEA (cm^2)	15.92	14.44	15.62	15.86	12.51	$\hat{Y}=14.86$	21.11	0.1087
SFT (mm)	2.61	2.61	2.58	2.47	1.52	$\hat{Y}=2.54024+0.35830TAN-0.14714TAN^2$. $R^2 = 0.25$	31.70	0.0069
FCC (1–5)(5)	3.39	3.36	3.36	3.50	2.37	$\hat{Y}=3.30119+0.38333TAN-0.14518TAN^2$. $R^2 = 0.21$	23.40	0.0149
Conformation (1–5)(5)	3.22	3.00	3.57	3.44	2.25	$\hat{Y}=3.06123+0.57150TAN-0.18415TAN^2$. $R^2 = 0.21$	25.78	0.0178
Color (1–5)(5)	3.06	2.86	2.86	3.06	2.75	$\hat{Y}=2.89$	13.88	0.2032
Marbling (1–5)(5)	2.72	2.43	2.71	2.31	2.12	$\hat{Y}=2.72269-0.14814TAN$. $R^2 = 0.12$	24.96	0.0338
Texture (1–5)(5)	3.44	3.36	3.50	3.50	3.31	$\hat{Y}=3.41$	14.99	0.7177
LCCS (cm)	58.14	58.44	59.33	57.92	56.61	$\hat{Y}=57.97$	5.70	0.2985
LLEG (cm)	37.87	37.16	37.26	36.82	36.09	$\hat{Y}=37.07$	6.92	0.1757
WLEG (cm)	10.08	8.90	10.93	10.37	8.59	$\hat{Y}=9.77$	17.21	0.3717
DLEG (cm)	14.46	14.43	15.33	14.40	13.59	$\hat{Y}=14.55$	9.48	0.4754
DBRST (cm)	23.59	23.74	22.90	23.20	21.51	$\hat{Y}=23.89364-0.43862TAN$. $R^2 = 0.16$	6.59	0.0130
Neck (%)	8.97	9.49	8.73	9.09	8.84	$\hat{Y}=9.00$	10.66	0.5399
Rib (%)	38.53	38.63	38.68	38.54	37.29	$\hat{Y}=38.35$	5.76	0.3417
Shoulder (%)	19.49	18.74	19.07	19.03	19.73	$\hat{Y}=19.20$	7.22	0.7666
Leg (%)	33.01	33.14	33.51	33.34	34.13	$\hat{Y}=33.44$	4.39	0.1251
TGIC (%)	16.13	15.81	15.99	17.96	22.72	$\hat{Y}=16.34415-1.86121TAN+0.84949TAN^2$. $R^2 = 0.44$	17.03	<.0001

(1)HCW, hot carcass weight; CCW, cold carcass weight; HCY, hot carcass yield; CCY, cold carcass yield; CLI, chilling loss index; BCI, carcass compactness index; LEA, loin eye area; SFT, subcutaneous fat thickness; FCC, fat content of the carcass; LCCS, carcass length; LLEG, leg length; WLEG, leg width; DLEG, leg depth; DBRST, breast depth; and TGIC, total gastrointestinal content. (2)TAN, level of black wattle tannin extract in the diet. (3)Coefficient of variation. (4)$p \leq 0.05$. (5)Scores on a visual scale from 1 to 5.

are important carcass characteristics that are directly related to the degree of finishing (represented by the body condition score) of the animals at slaughter. For these variables, the maximum values found were 2.76 and 3.55 mm, respectively, at 1.2 and 1.3% of tannin extract in the diet. These results can be explained by and are consistent with the body condition score of the animals at slaughter, for which the best value was obtained with 1.3% tannin extract. Although the maximum subcutaneous fat thickness value found in the present study is considered average and within the expected range for lambs (Mora et al., 2015), the animals fed 4.0% tannin extract in their diet had very little fat, representing a lack of finishing in their carcasses.

The maximum value obtained for carcass conformation was 3.5 at 1.6% tannin extract in the diet and is directly related to in vivo conformation, which also presented a value of 3.5 at this level. Therefore, evaluating the conformation of the animals before slaughter can be used for the assessment of the carcass of the lambs after slaughter. According to the scale of carcass conformation presented by Osório et al. (1998), the maximum value in the present study is considered very good, meaning that lambs fed 1.6% tannin extract in the total dry matter of the diet showed, not only a greater weight gain, but also carcasses with acceptable characteristics and a reasonable quality standard.

Conclusion

The addition of 1.6% black wattle (*Acacia mearnsii*) tannin extract to the total dry matter of the diet of lambs in confinement promotes the best gains in weight, body condition score, and conformation at slaughter.

References

BESHARATI, M.; MAGGIOLINO, A.; PALANGI, V.; KAYA, A.; JABBAR, M.; ESECELI, H.; DE PALO, P.; LORENZO. J.M. Tannin in ruminant nutrition: review. **Molecules**, v.27, art.8273, 2022. DOI: https://doi.org/10.3390/molecules27238273.

CHIAIA, H.L.J.; BALDI, F.; PEREIRA, A.S.C.; BANCHERO, G.; BRITO, G.; LA MANNA, A.; FERNANDEZ, H.; ACOSTA, Y.; MONTOSSI, F.; GASALLA, P.; MIGLIERINA, A.F.; NUÑEZ, A. Desempenho, características da carcaça e qualidade da carne de novilhos cruzados Hereford-Angus alimentados com silagem de grão úmido de sorgo. **Revista Brasileira de Saúde e Produção Animal**, v.17, p.685-695, 2016. DOI: https://doi.org/10.1590/S1519-99402016000400012.

COSTA, E.I. de S.; RIBEIRO, C.V.D.M.; SILVA, T.M.; BATISTA, A.S.M.; VIEIRA, J.F.; BARBOSA, A.M.; SILVA JÚNIOR, J.M. da; BEZERRA, L.R.; PEREIRA, E.S.; OLIVEIRA, R.L. Effect of dietary condensed tannins inclusion from *Acacia mearnsii* extract on the growth performance, carcass traits and meat quality of lambs. **Livestock Science**, v.253, art.104717, 2021a. DOI: https://doi.org/10.1016/j.livsci.2021.104717.

COSTA, V.R. da; CARVALHO, S.; GALLARRETA, B. da T.; LEAL, K.W.; SILVEIRA, J.M.; OLIVEIRA, M.D.F.A. de; TASCHETTO, E.A.; KASPER, M.A.; ULIANA, D. Feedlot-finishing lambs with different levels of soybean pre-cleaning by-product as the roughage source. **Semina: Ciências Agrárias**, v.42, p.1797-1812, 2021b. Supl.1. DOI: https://doi.org/10.5433/1679-0359.2021v42n3Supl1p1797.

COSTA, V.R. da; GALLARRETA, B. da T.; CARVALHO, S.; SARTORI, E.K.; GONÇALVES, C.; FARIAS, M.A.; ROSBACK, J.A.R. Characteristics of carcass and non-carcass components of lambs finished with different levels of waste from soybean pre-cleaning as a fibrous feedstuff. **Semina: Ciências Agrárias**, v.45, p.749-764, 2024. DOI: https://doi.org/10.5433/1679-0359.2024v45n3p749.

CUNNIFF, P. (Ed.). **Official methods of analysis of AOAC International**. 16th ed., 3rd ed. Gaithersburg: AOAC International, 1997. 1141p.

GEMEDA, B.S.; HASSEN, A. Effect of tannin and species variation on in vitro digestibility, gas, and methane production of tropical browse plants. **Asian-Australasian Journal of Animal Sciences**, v.28, p.188-199, 2015. DOI: https://doi.org/10.5713/ajas.14.0325.

GRANDIS, F.A.; RIBEIRO, E.L. de A.; MIZUBUTI, I.Y.; SILVA, L. das D.F. da; BUMBIERIS JUNIOR, V.H.; PRADO, O.P.P. do; CONSTANTINO, C.; FERNANDES JUNIOR, F.; MANGILLI, L.G.; PEREIRA, E.S. Desempenho, consumo de nutrientes e comportamento ingestivo de cordeiros alimentados com diferentes teores de torta de soja em substituição ao farelo de soja. **Revista Brasileira de Saúde e Produção Animal**, v.16, p.558-570, 2015. DOI: https://doi.org/10.1590/S1519-99402015000300008.

KOZLOSKI, G.V.; TREVISAN, L.M.; BONNECARRÈRE, L.M.; HÄRTER, C.J.; FIORENTINI, G.; GALVANI, D.B.; PIRES, C.C. Níveis de fibra em detergente neutro na dieta de cordeiros: consumo, digestibilidade e fermentação ruminal. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.58, p.893-900, 2006. DOI: https://doi.org/10.1590/S0102-09352006000500027.

LIMA, P.R.; APDINI, T.; FREIRE, A.S.; SANTANA, A.S.; MOURA, L.M.L; NASCIMENTO, J.C.S.; RODRIGUES, R.T.S.; DIJKSTRA, J.; GARCEZ NETO, A.F.; QUEIROZ, M.A.Á.; MENEZES, D.R. Dietary supplementation with tannin and soybean oil on intake, digestibility, feeding behavior, ruminal protozoa and methane emission in sheep. **Animal Feed Science and Technology**, v.249, p.10-17, 2019. DOI: https://doi.org/10.1016/j.anifeedsci.2019.01.017.

MIN, B.R.; SOLAIMAN, S. Comparative aspects of plant tannins on digestive physiology, nutrition and microbial community changes in sheep and goats: a review. **Journal of Animal**

Physiology and Animal Nutrition, v.102, p.1181-1193, 2018. DOI: https://doi.org/10.1111/jpn.12938.

MORA, N.H.A.P.; MACEDO, F.A.F.; MEXIA, A.A.; DIAS-SENEGALHE, F.B.; OLIVEIRA, E.Q.; RADIS, A.C. Características de carcaça de cordeiras Pantaneiras abatidas com diferentes espessuras de gordura subcutânea. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.67, p.290-298, 2015. DOI: https://doi.org/10.1590/1678-7319.

NRC. National Research Council. **Nutrient requirements of small ruminants**: sheep, goats, cervids, and new world camelids. Washington: National Academic Press, 2007. 384p. DOI: https://doi.org/10.17226/11654.

ORLANDI, T.; POZO, C.A.; MEZZOMO, M.P.; KOZLOSKI, G.V. *Acacia mearnsii* tannin extract as a feed additive: impact on feed intake, digestibility and nitrogen excretion by sheep fed a tropical grass-based diet. **Ciência Rural**, v.50, e20200095, 2020a. DOI: https://doi.org/10.1590/0103-8478cr20200095.

ORLANDI, T.; STEFANELLO, S.; MEZZOMO, M.P.; POZO, C.A.; KOZLOSKI, G.V. Impact of a tannin extract on digestibility and net flux of metabolites across splanchnic tissues of sheep. **Animal Feed Science and Technology**, v.261, art.114384, 2020b. DOI: https://doi.org/10.1016/j.anifeedsci.2019.114384.

OSÓRIO, J.C. da S.; SAÑUDO ASTIZ, C.; OSÓRIO, M.T.M.; ALFRANCA, I.S. **Produção de carne ovina**: alternativa para o Rio Grande do Sul. Pelotas: UFPEL, 1998. 166p.

SILVA, D.J.; QUEIROZ, A.C. de. **Análise de alimentos**: métodos químicos e biológicos. 3.ed. Viçosa: UFV, 2002. 235p.

SILVA, J.L.; GUIM, A.; FERREIRA, M.A.; SOARES, L.F.P. Forragens taníferas na produção de caprinos e ovinos. **Archivos de Zootecnia**, v.65, p.605-614, 2016.

SNIFFEN, C.J.; O'CONNOR, J.D.; VAN SOEST, P.J.; FOX, D.G.; RUSSELL, J.B. A net carbohydrate and protein system for evaluating cattle diets. II. Carbohydrate and protein availability. **Journal of Animal Science**, v.70, p.3562-3577, 1992. DOI: https://doi.org/10.2527/1992.70113562x.

SOUZA, M.R. de; VARGAS JÚNIOR, F.M. de; SOUZA, L.C.F. de; TALAMINI, E.; CAMILO, F.R. Análise econômica do confinamento de cordeiros alimentados com feno de capim piatã e soja *in natura* ou desativada. **Custos e @gronegócio Online**, v.10, p.131-151, 2014.

VIEIRA, L.V.; SCHMIDT, A.P.; BARBOSA, A.A.; FEIJÓ, J. de O.; BRAUNER, C.C.; RABASSA, V.R.; CORRÊA, M.N.; SCHMITT, E.; DEL PINO, F.A.B. Utilização de taninos como aditivo nutricional na dieta de ruminantes. **Arquivos de Ciências Veterinárias e Zoologia da UNIPAR,** v.23, e2306, 2020. DOI: https://doi.org/10.25110/arqvet.v23i1cont.2020.8040..

Author contributions

Mariana Dalla Favera Almeida de Oliveira: conceptualization, formal analysis, investigation, methodology, project administration, software, writing - original draft, writing - review & editing; Sérgio Carvalho: formal analysis (supporting), project administration (equal), supervision (lead), validation (equal); **Viviana Reboledo da Costa**: conceptualization (equal), investigation (equal), methodology (equal), project administration (equal), writing - review & editing (equal); **Bernardo da Trindade Gallaretta**: methodology (supporting); **Greicy Sofia Maysonnave**: funding acquisition (supporting); **Gabriela Pires Scherer**: funding acquisition (supporting), writing - review & editing (equal); **Danielle Dias Brutti**: funding acquisition (supporting), writing - review & editing (equal); **Daniel Uliana**: project administration (supporting), writing - original draft (supporting); **Pedro Henrique Galvão**: methodology (supporting); **Diúlia Zolin Galvani**: methodology (supporting), writing - original draft (supporting); **Camila Milani de Moraes**: methodology (supporting), writing - original draft (supporting).

Chief editor: Edemar Corazza
Edited by: Mírian Baptista

Data availability statement

Data in article: research data are available in the published article.

Declaration of use of AI technologies

No generative artificial intelligence (AI) was used in this study.

Conflict of interest statement

The authors declare no conflicts of interest.

Acknowledgments

To Seta S.A., for providing the black wattle tannin extract used in the study.

Disclaimer/Publisher's note