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Effects of feeding system during lactation and the inclusion of quebracho in the fattening on animal performance and carcass traits in light lambs

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ABSTRACT

BACKGROUND: In recent years, consumers have shown an increasing interest for products obtained from grazing animals or fed natural additives.

RESULTS: Ewes and their single male lamb (n=63) were fed indoors or grazed on alfalfa or on sainfoin during lactation. After weaning, lambs were fed concentrates with condensed tannins, from quebracho, or without them. Weight gains tended to be greater for Sainfoin lambs than for their counterparts (*P*<0.10). Indoor lambs had a greater dressing percentage and deposition of kidney fat than Sainfoin and Alfalfa lambs. The kidney fat of Sainfoin and Alfalfa lambs had a greater yellowness, chroma and carotenoid content than the fat of Indoor lambs (*P*<0.05), whereas the subcutaneous fat colour was not affected by the lactation feeding. Fat colour parameters did not trace the feeding system accurately.

The inclusion of 50g kg^{-1} quebracho in the concentrate during the fattening period increased the lamb intake (*P*=0.05) and tended to increase the lambs'

weight gains and the slaughter BW, but scarcely affected the carcass characteristics.

CONCLUSIONS: The feeding system during lactation had effect on the carcass characteristics, highlighting the importance of the dam's diet during this period. The inclusion of quebracho in the lamb's concentrate had minor effects.

Keywords: *indoor; sainfoin; alfalfa; fat colour; condensed tannins*.

INTRODUCTION

Traditional lamb meat, in Spain, is based on the production of light lambs To obtain this product, ewes and lambs are usually stalled indoors during the lactation period.[1] During this period, ewes are usually fed hay or straw plus concentrate, whereas lambs are almost exclusively milk-fed until weaning at 45-50 days of age. Thereafter, lambs receive a high-concentrate diet to obtain light carcass weight (8-12.5 kg). This indoor feeding system has the final objective of offering homogenous lamb carcasses with white fat and pale meat.[2] In recent years, consumers have shown an increasing interest in the production systems used to produce this meat, demanding a sustainable system.[3] Grazing is a sustainable production system that can satisfy the consumer demands.

Lactating ewes could graze on sainfoin (*Onobrychis viciifolia* Scop.) or alfalfa (*Medicago sativa* L.), two multiannual forage legumes that are widely used in Mediterranean areas. These two legumes are highly productive, with different growing patterns, and have high crude protein (CP) content and feed value for ruminants,[4] which makes them appropriate for the spring grazing of ovine. These two species, however, differ between them in the presence of condensed tannins (CT). In ruminants, in addition to the potential reduction of methane emissions, CT can improve animal performance, depending mainly on the structure and amount of condensed tannins present in the diet.[5, 6]

The effect of the inclusion of condensed tannins, have been studied in meat of fattening lambs,[7] with variable responses depending on the type and the dose of condensed tannins. The CT also can be including in the diet by the inclusion of quebracho extract (*Schinopsis lorentzii*) in the concentrate fed to lambs during the fattening period.

Therefore, the aim of this study was to evaluate the residual effect of the feeding system during the lactation period (Indoor, grazing alfalfa and grazing sainfoin) and the inclusion of quebracho extract in the concentrate fed to fattening lambs on the animal performance and carcass characteristics of light lambs.

MATERIAL AND METHODS

The experiment was conducted in the facilities of the CITA Research Centre in Zaragoza (41° 3´N, 0° 47´W, 216 m a.s.l.), which is located in the Ebro Valley, Northeastern Spain. The experiment and slaughter procedures were conducted in accordance with the requirements of the Spanish Policy for Animal Protection RD *53/2013* (BOE, n° 34, 8-2-2013), which meets the European Union Directive 2010/63 on the protection of animals used for experimental and other scientific purposes.

Animal management and experimental design

The experiment was of a 3 x 2 factorial design, comprising 3 feeding systems during lactation (Indoor, Sainfoin and Alfalfa) and 2 concentrates during the fattening period of the lambs (Control and QUE).

After lambing, 63 single-bearing ewes and their male lambs were randomly assigned to one of the three feeding systems during the lactation period. Each treatment was divided into two replicates. Treatments were balanced according to the lambing date, ewe BW, and lamb BW at the start of the experiment.

- Indoor: 21 pairs of ewes and lambs were permanently housed indoor, with free access to a dry total mixed ration and the lambs had access to a commercial concentrate. Each replicate was stocked in a separate pen.

- Sainfoin: 21 pairs of ewes and lambs were rotationally grazed on sainfoin and the lambs had access to a commercial concentrate. Each replicate was stocked in a separate paddock.

- Alfalfa: 21 pairs of ewes and lambs were rotationally grazed on alfalfa and the lambs had access to a commercial concentrate. Each replicate was stocked in a separate paddock.

During lactation, the lambs were kept permanently with their dams and had access to the commercial concentrate, in order to prepare them to the fattening period. During this period, pelleted concentrates were offered to lambs through a creep concentrate feeder, exclusive to them. Lambs were weaned when they reached 42±2 days of age.

After weaning, lambs were fed concentrates and straw *ad libitum*. Half of the lambs from each replicate, within each feeding system during lactation period, received a commercial concentrate (Control; Table 1) and the other half received the commercial concentrate with 50g kg^{-1} quebracho added

(SYLVAFEED ByPro Q, Adial Nutrition. Girona, Spain) for a CT concentration of 750g kg^{-1} (QUE). The groups within each replicate were balanced by BW at weaning. Each group of animals was allocated in a pen, with a total of twelve pens (6 or 5 lambs per pen) in the experiment. Water and mineral blocks were always offered *ad libitum*. Lambs were slaughtered when they reached a BW of 22-24 kg.

In September 2013, sainfoin and alfalfa were seeded at 90 and 25 kg seed ha^{-1}, respectively, in two 1 ha plots for each crop. Each plot was divided into 5 paddocks. The plots were fertilised annually with 100 kg ha^{-1} of 0:10:10 of nitrogen:phosphorus:potassium. The plots were irrigated fortnightly. Grazing animals were changed to a new paddock at 7-10 days, to ensure that the stubble height remained above 10 cm. The phenological stage of both forages during the lactation period was the vegetative-early flowering stage.

The main components of the total mixed ration offered to the indoor dams were barley straw (500 g kg^{-1}), barley grain (115 g kg^{-1}), corn grain (116 g kg^{-1}), protein grain 170 g kg^{-1} CP (93 g kg^{-1}), rapeseed meal (70 g kg^{-1}), soya bean meal (33 g kg^{-1}) and sugar-beet molasses (350 g kg^{-1}). The Control concentrate components were corn (350 g kg^{-1}), soya bean meal (238 g kg^{-1}), wheat (200 g kg^{-1}) and barley (150 g kg^{-1}). The main ingredients of the QUE concentrate were corn (400 g kg^{-1}), soya bean meal (263 g kg^{-1}), wheat (200 g kg^{-1}) and quebracho (50 g kg^{-1}).

Measurements and sampling procedures

Grazing herbage mass was measured weekly by clipping with an electrical mower and registering all plant material 5-7 cm above ground level in five 0.25

m^2 quadrats randomly located in the paddock. Sward height was measured weekly by taking 50 points evenly distributed within the paddock. The samples were dried at 60 °C until constant weight to determine the forage DM production. Thereafter, they were ground through a 1 mm screen and stored for further chemical analysis. Fresh samples of the feedstuffs were frozen at -80 °C until CT analysis.

Ewes and lambs were weighed weekly at 8:00 am with an electronic balance (0.1 kg precision). The body condition score (BCS) (0 to 5 scale) of the ewes was measured weekly by two trained technicians.[8] Lambs' weight gains were estimated by a linear regression of BW against time. The amount of total mixed ration and concentrate offered, and their refusals, were registered weekly by pen or paddock. Likewise, the intake was calculated weekly by paddock or pen.

When the lambs reached the target slaughter weight, they were slaughtered weekly in the experimental abattoir of the Research Centre. After slaughter, carcasses were weighed to obtain the hot carcass weight. Carcasses were hung by the Achilles tendon and chilled at 4°C for 24 h in total darkness. Thereafter, the cold carcass weight was registered. The dressing percentage was calculated as $(\text{cold carcass weight}/\text{slaughter weight})\ \text{x}\ 100$, and the carcass shrinkage as $[(\text{hot carcass weight} - \text{cold carcass weight})/\text{hot carcass weight}]\ \text{x}\ 100$. Next, the kidney fat deposits were extracted and weighed. The instrumental colours of the subcutaneous and kidney fats were measured using a Minolta CM-2006d spectrophotometer (Konica Minolta Holdings, Inc., Osaka, Japan) in the CIELAB space.[9] The diameter of the measured area was 8 mm, including a specular component and 0% UV; standard illuminant D65, which simulates daylight (colour temperature 6504 K); a 10° observer angle; and zero and white calibrations. All measures were carried out with a white tile below the samples. The lightness (L*), redness (a*) and yellowness (b*) were recorded, and the hue angle (H°) index was calculated as tan-1 (b*/a*) x 57.29 $\tan - 1\ (b^*/a^*)\ x\ 57.29$, expressed in degrees and chroma (C*) as $\sqrt{(a^{*2} + b^{*2})}$. The proportion of reflected light every 10 nm between 450 and 510 nm was collected, and the absolute value of the integral of the translated spectrum (SUM) was calculated according to Prache and Theriez.[10] This variable was used to estimate the carotenoid pigment content of fat.

Chemical analysis

Feedstuffs dry matter and ash contents were determined according to the AOAC methods,[11] and NDF, ADF and ADL analyses were carried out following the sequential procedure of Van Soest *et al.*[12] with an Ankom 200/220 fibre analyser (Ankom, NY, USA). Acid detergent lignin was analysed on ADF residues by the solubilisation of cellulose with sulphuric acid. All values were corrected for ash-free content. Crude protein content (Nitrogen x 6.25) was determined following the Dumas Procedure,[11] using a nitrogen analyser (Model NA 2100, CE Instruments, Thermoquest SA, Barcelona, Spain). Condensed tannin content was determined with the colourimetric HCl-butanol method described by Grabber,[13] using cyanidin as a standard.

Statistical analyses

Data were analysed using SAS statistical software (SAS V.9.3). The BW and BCS were analysed using mixed models (mixed procedure) for repeated measures, including the feeding system during lactation, the inclusion of QUE in the concentrate, the time and their interactions as fixed effects and the animal as the random effect. The degrees of freedom were adjusted with the Kenwardroger correction to account for possible unequal observations per ewe or missing values. To model the experimental error, different variance-covariance matrices were tested and the one with the lowest Akaike and Bayesian Information Criteria was selected. Concentrate intake and carcass characteristics were analysed through analysis of variance with a general linear model (GLM procedure), with the feeding system during lactation, the inclusion of QUE in the concentrate and its interaction as fixed effects. The results were reported as least square means and their associated standard errors (SE). Multiple comparisons among treatments were performed using the Tukey's test. A forward stepwise discriminant analysis was carried out for the subcutaneous caudal and kidney fats, with L*, a*, b*, C*, H° and SUM as the variables evaluated.

RESULTS

The interaction between the feeding system during the lactation period and the inclusion of QUE in the concentrate during the fattening period was not significant (P>0.05) in any of the studied parameters. Consequently, the results are presented separately for these main effects.

Feedstuffs

Alfalfa and sainfoin presented different distributions of mass production throughout the studied period. Alfalfa had an average weekly available biomass of 3,089±279 kg DM ha^{-1} (49±6 cm height), with the minimum production at the beginning (1,391±240 kg DM ha^{-1}) and the maximum at the end of the experimental period (4,314±240 kg DM ha^{-1}). The average biomass refusal was 867±178 kg DM ha^{-1} (15±8 cm height). Sainfoin had an average weekly available biomass of 4,411±276 kg DM ha^{-1} (79±8 cm height) with the maximum production in the middle of experimental period (7,568±240 kg DM ha^{-1}) and the minimum production at the end of the trial (1,380±240 kg DM ha^{-1}) (Figure 1). The average biomass refusal was 2,430±745 kg DM ha^{-1} (50±12 cm height). Regardless of the different masses presented in the alfalfa and sainfoin paddocks, the herbage mass was not limiting throughout the experiment. The average total mixed ration intake was 1.95±0.03 kg DM head^{-1} day^{-1}.

The average chemical composition of the feedstuffs is reported in Table 1. The chemical composition of the total mixed ration and concentrates remained constant (data not shown) while the composition of alfalfa and sainfoin changed throughout the experiment (Figure 1). On average, the total mixed ration fed to the Indoor ewes presented the lowest CP content and the lowest fibre content. The chemical composition of alfalfa and sainfoin was similar, and evolved similarly throughout the grazing period, except for the last sampling when alfalfa presented with greater CP and lower NDF content than sainfoin (Figure 1). Sainfoin had a large amount of total CT (Table 1), which was minimal in the remaining feedstuffs.

The quality of the concentrates was similar, except for the total CT, as the QUE concentrate presented greater content than the Control concentrate.

Animal performance

Ewe BW was affected by the feeding system and the week (*P*<0.001). In the first weeks of the experiment, BW did not differ among feeding systems, but Indoor ewes had a greater BW than the Alfalfa and Sainfoin ewes in the last three weeks (*P*<0.05; Figure 2). Similarly, the BCS did not differ among treatments in the first weeks, but in concordance with the BW, Indoor ewes had greater scores in the last two weeks of lactation (*P*<0.05). Alfalfa and Sainfoin ewes maintained their BW and BCS throughout lactation period.

The BW of lambs at birth and weaning were not affected by the feeding system during lactation period (*P*>0.05; Table 2). However, Sainfoin lambs tended to grow faster than Alfalfa and Indoor lambs (*P*<0.10). The total concentrate intake during lactation was approximately 3-fold greater for Indoor than for Alfalfa and Sainfoin lambs (*P*<0.001).

The feeding system during the lactation period did not have an effect on lamb performance during the subsequent fattening period (Table 3; *P*>0.05). The slaughter BW, however, tended to be different between Sainfoin and their counterparts (*P*=0.09). The inclusion of quebracho in the concentrate tended to increase the weight gains (*P*=0.08), DMI (*P*=0.05) and consequently, slaughter BW (*P*=0.06), but did not affect the age at slaughter (*P*>0.05).

Carcass characteristics

The feeding system during lactation affected most of the lamb carcass characteristics (Table 4). The Indoor lambs had greater hot and cold carcass weights (*P*<0.05) than Alfalfa lambs, with Sainfoin lambs having intermediate weights (*P*>0.05). The dressing percentage and kidney fat deposits were greater in Indoor lambs than in Sainfoin and Alfalfa lambs (P<0.001). There were no differences in carcass shrinkage (P>0.05).

The feeding system during lactation affected colour and SUM in the kidney fat, but not in subcutaneous fat deposits (Table 4). In the kidney fat deposits, the feeding system during lactation affected the redness (P<0.05), yellowness (P<0.001), Chroma (P<0.001) and SUM (P=0.05), but not lightness and hue values (P>0.05). The kidney fat in Indoor carcasses had a lower redness value and higher in Sainfoin carcasses (P<0.05), whereas Alfalfa had intermediate values (P>0.05). In contrast, the kidney fat in Alfalfa and Sainfoin carcasses had greater yellowness, chroma (P<0.001) and SUM (P=0.05) values than in Indoor carcasses.

The inclusion of quebracho in the concentrate during the fattening period had no effect on carcass characteristics (P>0.05), except for a tendency to decrease carcass shrinkage (P<0.10; Table 4). In regards to fat colour, it had no effect on the colour of the renal fat deposits (P>0.05), but it affected some parameters of the subcutaneous fat (P<0.05). The inclusion of quebracho in the concentrate reduced redness, yellowness and chroma values (P<0.05) compared with the Control concentrate, with no effect on lightness, hue and SUM (P>0.05).

The discriminant analysis showed that the kidney fat colour and SUM variables classified correctly 57.1% of Alfalfa, 52.4% of Sainfoin and 66.7% of Indoor carcasses. The subcutaneous caudal fat variables better classified Alfalfa than Sainfoin and Indoor carcasses. Overall, these variables can correctly classify 58.73% of carcasses when they are recorded from the kidney fat and 47.62% when they are from subcutaneous caudal fat (Table 5).

DISCUSSION

The aim of using sainfoin and alfalfa was to compare two forages that differed in CT concentrations but were similar in other chemical parameters. The total mixed ration was included in the study to have a comparison with the most common system in this area. Before recommending the forage-based system to the farmers as alternative to the indoor system, the grazing system must be evaluated from a holistic point of view, considering not only animal production but also carcass and meat quality.

The evolution of sainfoin and alfalfa production in the current experiment agrees with previous studies. Sainfoin is characterised by a high forage production in spring at the first cut, followed by a low capacity for regrowth, resulting in a noticeably lower production in subsequent cuts,[14] while alfalfa has a more steady forage production.[15]

The similar chemical composition, except for slightly different protein content, related to the leaf-to-whole-plant ratio of alfalfa and sainfoin, and the different CT content is in line with Theodoridou *et al*.[4]

Animal performance

The greater BW presented by Indoor ewes at the end of lactation can be related to their lower energy requirement for maintenance since they spent less time walking and eating than grazing ewes.[16] In addition, the total mixed ration fed to indoor ewes had a lower ADF content and, consequently, a greater metabolisable energy content (according to the estimations proposed by Mertens[17]) than the forages. Sainfoin and Alfalfa ewes presented with similar BW and BCS, because the forages contained similar fibre content and the herbage mass was not limited throughout the experiment. Consequently, the grazing of sainfoin and alfalfa by lactating ewes is advisable, as it allowed the maintenance of BW and BCS of ewes rearing one lamb and allowed a good growth of lambs.

In regards to the performance of the suckling lambs, the slightly higher weight gains of Sainfoin lambs could be partially related to the milk yield due to the presence of moderate concentration of CT in the dam's diet.[18] However, Hoste *et al*.[19] did not observed differences in goats fed sainfoin or alfalfa on milk yield. The results from the literature are confusing and depend on the type and dose of CT.[6] The lower ADG observed in indoor lambs during lactation period, might be due to a lower milk yield. Galvani *et al*.[20] concluded that the growth rate of lambs from birth to 42 days old is significantly correlated with milk intake (r=0.74; P<0.01). However, in the present study we cannot confirm this, as milk had not been assessed. The greater concentrate intake observed in Indoor lambs during lactation period might be related to a lower milk yield, supporting the observation of the abovementioned authors.

The effect of the diet during lactation on the performance during the posterior fattening of lambs has not been widely studied. As the feeding systems studied during lactation in the present experiment did not affect the lamb performance during the posterior fattening period, grazing either legume studied during lactation can be a sustainable feeding system.

During the fattening period, lambs fed QUE showed a greater weight gains (6.5%) which could be linked both to the greater intake of concentrate and to the presence of CT in the concentrate. The effect of the inclusion of CT in the concentrate on weight gains depends on both its dose and the CP content of the diet.[21] The inclusion of quebracho in the concentrate fed to weaned grazing lambs increased weight gains when they were fed a concentrate low in CP, but not when they were fed a high CP concentrate.[22] According to the abovementioned study, when CP was high, quebracho did not contribute any further protein supply in the small intestine. In a diet with intermediate CP content (175g kg^{-1}), an inclusion of 20 g kg^{-1} quebracho increased weight gains, but not inclusions of 10 and 30 g kg^{-1} quebracho.[23] At high doses (89 g kg^{-1}) of quebracho in the concentrate, the weight gains in lambs decreased.[21] Thus, the inclusion of a source of CT in the concentrate with a low-medium CP should be further studied, in order to discern if the presence of CT can improve the productive efficiency of these diets.

Similarly, the effect of the inclusion of quebracho in the concentrate on the voluntary intake depends on the proportion added. In the current experiment, the medium proportion of quebracho increased concentrate intake, whereas large quantities have been shown to reduce the intake,[21] and low proportions had no effect.[24] The result of the current experiment must be confirmed in future studies, because the literature on the increase of the intake with quebracho or other CT sources is scarce. It would be interesting to study the inclusion of different doses of quebracho in the concentrate to improve lamb intake and growth.

Carcass characteristics

The greater dressing percentage presented by Indoor carcasses, when compared to Sainfoin or Alfalfa carcasses, can be related to the greater amount of abdominal fat in the forage treatments because grazing lambs had greater mesenteric fat than Indoor lambs.[2, 25] The noticeably greater deposition of kidney fat in Indoor lambs could be related to the greater intake of concentrate during lactation and lower levels of physical exercise.

Yellowness and chroma are the most appropriate parameters for assessing fat colour.[26] The greater yellowness and chroma in the kidney fat, but not in the subcutaneous fat, observed in the Alfalfa and Sainfoin treatments are related to the precocity of the fat deposits. The kidney fat deposit develops earlier than the subcutaneous fat, which is deposited later.[2, 27] The greater SUM values of kidney fat from Sainfoin and Alfalfa carcasses than Indoor carcasses are related to the intake and posterior deposit of carotenoid pigments, which are lipophilic compounds. These pigments are transferred through the milk and deposited in the lamb fat deposits.[28] In addition, when suckling lambs graze, they may ingest carotenoids directly from the forage, although forage intake is minimum.[29] On the other hand, the finishing period of less than 30 days after weaning could have diluted the carotenoids in the fat,[30] causing the differences due to the feeding treatment in lactation to vanish in the subcutaneous fat. Similarly Ripoll *et al*.[31] also observed that alfalfa grazing lambs had increased yellowness and chroma in the renal fat, but not in the subcutaneous fat when compared to the indoor fed lambs.

The effect of the inclusion of quebracho in the concentrate during the fattening period on carcass weights varies between studies. In agreement with the present results, Dawson *et al*.[22] reported similar carcass characteristics when 0, 80 or 100 g of quebracho kg^{-1} FM was included in the diet of lambs. However, when CT, regardless of the source of CT,[21, 32] reduced BW at slaughter, it consequently also reduced the carcass weight.

Fat colour parameters are an easy, cheap and reliable tool to trace the feeding management of ruminants. For this reason, some authors have proposed the use of spectral methods to achieve this authentication, primarily by using the information contained in the visible reflectance spectrum of animal tissues.[30, 33] The results of the discriminant analysis were mediocre-poor in the framework of searching for a good tool to authenticate the feeding system during lactation. Better results were obtained in grazing and indoor light lambs on kidney subcutaneous fat colours.[33] In the present study, the concentrate-feeding during the fattening period may have interfered. Thus, diet authentication is more accurate when the different diets are fed just before slaughter. More studies searching for the tools to trace the feeding system should be performed.

CONCLUSIONS

The feeding system during lactation had little influence on ewe and lamb productive parameters, so all the systems are suitable for producing light lambs. Unexpectedly, the feeding system during the lactation period had effect on the carcass characteristics of light lambs, highlighting the importance of the dam's diet during this period. The kidney fat colour of light lambs was greatly affected by the feeding system during lactation, although it is not possible to accurately trace the system during this period. The inclusion of 50g kg^{-1} quebracho in the concentrate during the fattening period had minor effects on lamb performance and carcass quality. The effects of both factors (feeding treatment during lactation and the inclusion of quebracho in the concentrate) on meat quality should be evaluated.

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Table 1 Chemical composition (g kg^{-1} dry matter) of the forages used during the lactation period and the concentrates used during the fattening period.

	Ewe's feedstuffs[1]			Lamb's concentrates[2]	
Item	Alfalfa	Sainfoin	Total mixed ration	QUE	Control
Moisture	919.5	916.0	924.1	889.1	886.1
Ash	90.4	78.4	47.9	53.8	54.3
Crude protein	189.7	161.3	109.1	210.1	195.4
Neutral detergent fibre	454.9	451.9	426.9	176.5	177.7
Acid detergent fibre	310.2	352.0	199.9	41.1	43.6
Acid detergent lignin	66.8	82.7	25.3	6.3	6.0
Total CT[3], cyanidin equivalent	1.5	21.9	0.8	3.7	0.6

[1] Indoor=Ewes fed a total mixed ration; Alfalfa=grazing on alfalfa; Sainfoin=grazing on sainfoin. [2] Control=commercial concentrate; QUE=commercial concentrate with 50g kg^{-1} quebracho. CT[3]=Condensed tannins.

Table 2 Effect of the feeding system during lactation[1] on lamb productive parameters.

	Alfalfa	Sainfoin	Indoor	SEM	P-value
N	21	21	21		
Lambing date	3/04	3/04	4/04	1.7	0.34
Birth BW, kg	3.9	4.1	3.9	0.3	0.67
Weaning BW, kg	14.6	15.7	15.4	1.0	0.38
Weight gains, g d^{-1}	293	317	283	22	0.07
Age at weaning, d	42	41	43	2	0.55
Total concentrate intake, kg DM	1.25[b]	1.39[b]	4.22[a]	0.17	0.001

[1] Alfalfa=grazing on alfalfa; Sainfoin=grazing on sainfoin; Indoor=Ewes fed a total mixed ration.

Table 3 Effect of the feeding system during lactation (L) and the inclusion of quebracho in the concentrate during fattening (F) on lamb productive parameters during the fattening period.

	Lactation[1]			Fattening[2]			P-value	
	Alfalfa	Sainfoin	Indoor	QUE	Control	SEM	L	F
n	21	21	21	32	31			
Weight gain, g d^{-1}	288	275	276	289	270	16	0.54	0.08
DMI, g d^{-1}	818	840	845	900	768	40	0.92	0.05
Slaughter BW, kg	22.9	23.5	22.9	23.4	22.9	0.4	0.09	0.06
Age at slaughter, d	70	69	70	68	71	4	0.91	0.33

[1]Alfalfa=grazing on alfalfa; Sainfoin=grazing on sainfoin; Indoor=Ewes fed a total mixed ration.

[2]Control = commercial concentrate; QUE=commercial concentrate with 50g kg^{-1} quebracho.

Table 4 Effects of the feeding system during lactation (L) and the inclusion of quebracho in the concentrate during fattening (F) on carcass characteristics of light lambs.

	Lactation[1]			Fattening[2]			P-value	
	Alfalfa	Sainfoin	Indoor	QUE	Control	SEM	L	F
Hot carcass weight, kg	10.6^{b}	11.1^{ab}	11.3^{a}	11.1	10.8	0.2	0.03	0.15
Cold carcass weight, kg	10.3^{b}	10.8^{ab}	10.9^{a}	10.84	10.5	0.2	0.03	0.10
Dressing percentage, %	44.9^{b}	45.7^{b}	47.8^{a}	46.4	45.9	0.6	0.001	0.40
Carcass shrinkage, %	2.8	2.5	2.7	2.4	2.9	0.2	0.54	0.07
Kidney fat, g	123.7^{b}	140.1^{b}	227.3^{a}	167.7	159.7	16.0	0.001	0.64
Kidney fat colour								
Lightness (L*)	73.38	73.1	73.92	73.91	73.02	0.57	0.5	0.12
Redness (a*)	4.02^{ab}	4.24^{a}	3.41^{b}	3.77	4.01	0.27	0.04	0.38
Yellowness (b*)	11.89^{a}	11.60^{a}	10.05^{b}	11.04	11.33	0.39	0.001	0.47
Hue (H°)	71.28	69.98	71.56	71.17	70.71	1.04	0.42	0.66
Chroma (C*)	12.59^{a}	12.39^{a}	10.64^{b}	11.71	12.04	0.42	0.001	0.43
SUM	150.66^{a}	148.15^{a}	115.91^{b}	142	134.5	12.7	0.05	0.56
Subcutaneous fat colour								
Lightness (L*)	69.81	70.37	69.92	70.51	69.56	0.67	0.77	0.16
Redness (a*)	2.86	2.56	2.79	2.47	3.01	0.26	0.62	0.04
Yellowness (b*)	11.51	10.89	10.74	10.56	11.53	0.4	0.26	0.02
Hue (H°)	76.28	77.12	75.54	77.04	75.58	1.07	0.49	0.18
Chroma (C*)	11.90	11.21	11.12	10.87	11.95	0.42	0.27	0.01
SUM	100.21	90.45	86.17	96.66	87.9	10.9	0.57	0.43

[1]Alfalfa=grazing on alfalfa; Sainfoin=grazing on sainfoin; Indoor=Ewes fed a total mixed ration. [2]Control=commercial concentrate; QUE=commercial concentrate with 50g kg^{-1} quebracho. [a,b] Means within a row with different superscripts differ significantly among feeding system during lactation ($P < 0.05$).

Table 5 Discriminant classification, expressed on the percent of carcasses rightly classified, for kidney fat (KF) and subcutaneous caudal fat (SCF)

Origin	Predicted[a]					
	Alfalfa[1]		Sainfoin[1]		Indoor[1]	
Fat depot	KF	SCF	KF	SCF	KF	SCF
Alfalfa	57.1	66.7	38.1	14.3	4.8	19.0
Sainfoin	42.9	33.3	52.4	38.1	4.8	28.6
Indoor[b]	9.5	14.3	23.8	47.6	66.7	38.1

[a] Analysis included L*, a*, b*, H°, C* and SUM.

[1]Alfalfa=grazing on alfalfa; Sainfoin=grazing on sainfoin; Indoor=Ewes fed a total mixed ration.

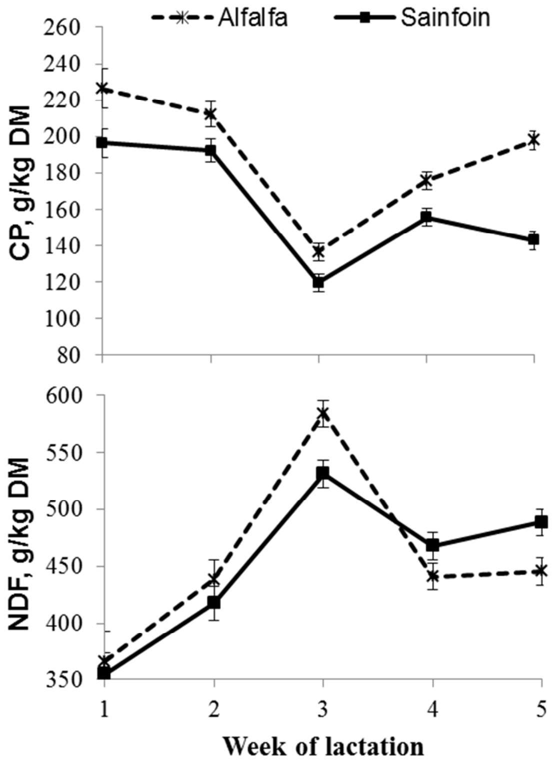

Figure 1 Crude protein (CP) and neutral detergent fibre (NDF) of afalfa and sainfoin forages throughout the lactation period studied.

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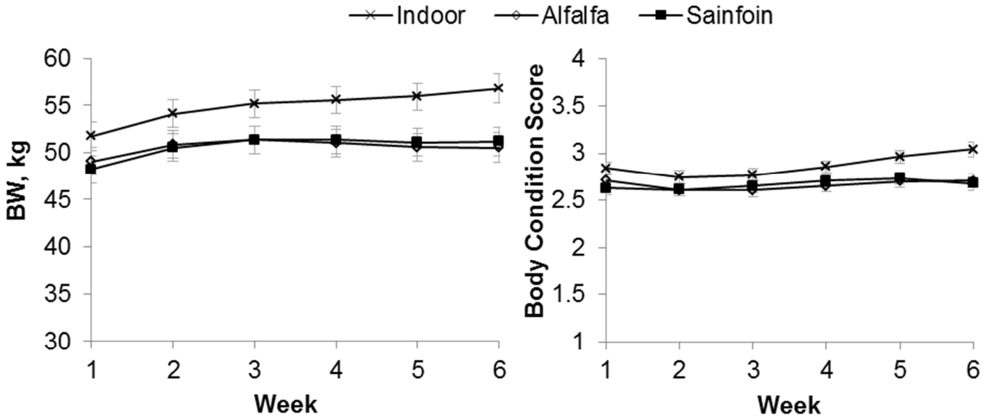

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532 **Figure 2** Evolution of the BW and body condition score (BCS) for ewes grazing

533 on Alfalfa or Sainfoin, or Indoor fed a total mixed ration.