EFFECT OF DIFFERENTR LEVELS OF QUEBRACHO TANNINS ON THE *IN VITRO* RUMINAL DEGRADATION AND GROWTH PERFORMANCE OF SHEEP

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ABSTRACT

This study was carried out to evaluate the effect of addition of different levels of quebracho tannin (QT) to alfalfa hay on the in vitro degradation kinetics of dry matter (DM), fiber fractions and nitrogen (N). The concentrations of total and individual volatile fatty acids (VFA) were also determined. The performance of growing Najdi lambs as affected by supplying alfalfa hay with QT was studied by using 24 lambs. Alfalfa hay was treated with QT at the levels of 0, 1, 2 and 3% of DM to form four treatments of QT0, QT1, QT2 and QT3, respectively. Rapidly degraded fraction (a) of DM was not affected by either low or moderate levels of QT treatment (i.e. QT1 or QT2), while this fraction significantly declined at QT3 level. The slowly degraded fraction (b) of DM was significantly ($P<0.05$) depressed when alfalfa hay was treated with QT3 level, while the other treatments were not effective. Degradation rate (c) declined insignificantly in all treated hay compared with control. Time needed to start degradation (L_0) was significantly ($P<0.05$) longer at QT3 compared with the control. The inhibitory effect of QT at the level of 3% was observed for b fraction, c and effective degradability (ED) of neutral detergent fiber (NDF). The L_1 was also significantly ($P<0.05$) increased at QT3 level. The degradation parameters for acid detergent fiber (ADF) show similar trend as for NDF. The b fraction was 36.5, 38.8, 38.9 and 29.2%; the C value was 0.029, 0.028, 0.027 and 0.023 (%/h); and ED was 15.7, 16.1, 15.8 and 10.7% for QT0, QT1, QT2 and QT3 respectively. The degradation constants (a, b and c) were significantly ($P < 0.05$) decreased in QT2 and QT3 compared to QT0, while alfalfa hay treated with 1% of QT had minor effect on degradation constants.

Concentration of total VFA (mM) after 24 h of in vitro incubation was significantly ($P<0.05$) lower for QT3 compared with control. The proportions of acetate, propionate, n-butyrate and iso-butyrate were not affected by treatment compared to QT0. The ratio of acetate to propionate was significantly lower for QT3 compared to QT0, while values for QT2 were lower than control with no significance difference.

Total body weight gain, average daily gain and relative weight gain were significantly higher for QT2 as compared to the control, while QT1 and QT3 had intermediate values. Feed conversion were not significantly different among all diets, but the feed conversion for QT2 was improved by about 18% compared to QT0.

Addition of QT to alfalfa hay reduced the in vitro rumen degradability of DM and N in a dose-dependent manner. Reduction of rumen degradability of N in QT2 is beneficial for lambs as it increases the gain of lambs.

***Key words**: quebracho tannin, alfalfa hay, degradation kinetics, volatile fatty acids, gain.*

INTRODUCTION

The rapid and excessive degradation of protein during rumen fermentation can reduce the efficiency of N utilization in ruminants (Broderick & Clayton 1992; Van Horn *et al.* 1996). Major consequences of reduced N utilization are the increasing cost of supplemental protein to compensate for the high ruminal losses of feed protein and the excessive N excretion in urine that potentially contributes to N contamination of surface and groundwater. Optimum microbial protein synthesis was achieved when the ratio between hourly release of N and organic matter (OM) was 25g N/ kg of ruminally degraded OM (Sinclair *et al.* 1995). This ratio was found to be 34.5g N/ kg OM, when sheep were fed berseem hay (*Trifolium alexandrinum*) as a sole diet (Kamel *et al.* 2004), and NH_3-N concentration of rumen liquor was raised to be 8.28 mM (Kamel *et al.* 2000) that was higher three times than the minimum level recommended by Satter and Slyter (1974) for microbial protein synthesis.

Tannins are phenolic compounds with various molecular weights and variable complexity with protein. They are tentatively classified into two classes, hydrolysable and condensed tannins (CTs). A unique chemical property of tannins is their affinity to bind to feed protein and thereby reduce excessive breakdown of protein in the rumen (Getachew *et al.* 2000; Makkar 2003; El-Waziry et al., 2005; El-Waziry et al., 2007) and increase the availability of high quality protein for absorption in the lower gut of the ruminants (Waghorn *et al.* 1987).

The addition of tannin as a natural extract has considerable merit to protect dietary protein compared to other techniques (i.e. physical and chemical). High temperature during physical treatment might increase the maillard reaction, and also using formaldehyde in chemical treatments could be toxic for the animal at high doses. Due to their strong protein binding ability, tannins have a potential to reduce the rate and extent of protein degradation in the rumen. Moderate concentration of tannins had a significant positive effect on nutrition of ruminants (Barry & McNabb 1999), but at higher concentrations, tannins reduce dry matter intake (Pritchard *et al.* 1992), dry matter degradability (Getachew *et al.* 2000; Hervás *et al.* 2003) and fiber degradability (Hervás *et al.* 2003).

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The determination of optimum tannin levels for improving nitrogen supply and utilization presents a considerable challenge to animal nutritionists. The objectives of this study were: (1) to clarify the effect of different levels of quebracho tannin (QT, condensed tannin, CT) on the *in vitro* ruminal degradation of DM, fiber fractions and N; and (2) to know the effect of QT level on growth performance of lambs fed alfalfa hay as a sole diet.

1- MATERIALS AND METHODS

2-1 Experimental site and diet characteristics

This study was carried out at the Agricultural Researche Station of Qasssim University. A QT source (Unitan ATO, Saica, Argentina) from Quebracho plant (*Schinopsis* spp.) was used as a condensed tannins (CTs) additive. The QT contained 75% (w/w) CTs on DM basis. Alfalfa hay was ground (4 mm), then was thoroughly mixed with QT at levels of 0, 1, 2 and 3% of DM to form four treatments of QT0 (control), QT1, QT2 and QT3, respectively. The actual levels of CTs in DM of these treatments were 0, 0.75, 1.5 and 2.25% (w/w), respectively. The mixture of alfalfa hay and QT was mechanically pelleted using steam at 85 °C then was crumbled. Alfalfa hay contained 86.3, 2.8, 43.9, 25.3 and 5.2% of DM for OM, N, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL), respectively.

2-2 In *vitro* determination of rumen degradation kinetics of DM, NDF, ADF and N

Two ruminally cannulated rams with average live weight of 55.7 kg were used as a source of rumen contents to carry out an *in vitro* experiment. Rams were fed the four experimental diets (control, QT1, QT2 and QT3) at 3% of their body weight in two equal portions at 06.00 and 16.00 hours, and had access to drinking water and to lick mineral blocks freely. For each treatment (i.e. control, QT1, QT2 and QT3), the feeding period was 28 d, and on the day 16th rumen contents were collected for *in vitro* experiment. Samples of rumen contents were obtained from the two rams were mixed and squeezed through four layers of cheesecloth into pre-warmed flasks to separate the liquid from solid fractions. An automatic incubator (Daisy^{II} incubator; ANKOM Technology, NY, USA) with 4-glass bottles was used for the *in vitro* study. To begin the *in vitro* experiment, each glass was filled with 360 mL of rumen fluid and 1440 mL artificial saliva (Hungate 1966) and was kept in an incubator adjusted at 39 °C.

Five grams of ground QT-treated alfalfa hay (1-mm screen) were accurately weighed into synthetic bags with a pore size of 45 µm (Swiss Nylon Monofilament, Luzern-Switzerland). Twenty-four bags were used at each treatment, bag size was 5x10 cm. Six bags for each glass bottles were incubated, then one bag was removed after intervals of 3, 6, 12, 24, 48 or 72h. Tannin-treated alfalfa hay (i.e. QT0, QT1, QT2 and QT3) were incubated with rumen fluid obtained from the animals fed the same treated-alfalfa hay. After incubation, the bags and hay residues were washed by a running tap water until the water became clear, and were squeezed gently. Microorganisms attached to the residual samples were eliminated by a freezing-rethawing technique as described by Kamel *et al.* (1995). During the withdrawal of bags from glasses bottles, the glasses were flushed with oxygen-free CO_2. Two un-incubated bags for each treatment were washed by the same procedure to measure the washing loss fraction. After washing, the bag contents were dried in an oven at 60 °C for 48h and reweighed. Residuals of DM, NDF, ADF, and N were determined in each bag. Degradability coefficients were calculated by fitting the data for DM, NDF, ADF, and N disappearances to the model of McDonald (1981) as follows:

$P = a + b\,(1\text{-}e^{-c(t-Lt)})$,

where P is the cumulative amounts of DM, NDF, ADF, and N degraded at time t, a is the readily degraded fraction, b is the fraction potentially degraded in the rumen, c is the rate constant of degradation of b, and t is the incubation time in hours. The lag time (L_t) was estimated according to McDonald (1981). Outflow rate was assumed to be 0.03 per h (AFRC 1993).

2-3 Determination of volatile fatty acids

The *in vitro* incubation system (gas method) as described by Menke et al. (1979) was used to measure volatile fatty acid (VFA) concentrations of tested diets. Buffered rumen liquor (2:1 v/v) was prepared as described by Menke and Steingass (1988). About 200 mg DM (1 mm) of the each treatment was weighed into calibration syringes (60 ml). Syringes pistons were lubricated with vaseline to ease their sliding and to prevent escape of gas. Syringes were pre-warmed to 40 °C before with drawl of 30 ml of rumen liquor-buffer mixture into each syringe, followed by incubation in a water bath at 39± 0.1 °C. Three parallel syringes that contained rumen liquor-buffer mixture without substrate served as blanks. At the end of incubation (24 hrs), the supernatant of each syringe was centrifuge at 5000 *xg* for 10 min and sampled, then stored at –20 °C pending analysis for VFA concentration. Gas chromatograph (Shimadzu 2010A) equipped with a FID detector, and a fused silica capillary column of 30 m × 0.25 mm i.d.; 0.25 µm phase film (Stabiwaz-DA; Thames Restek UK, LTD) was used. The split ratio in the injector port was 50:1 with a linear velocity of 10 mL/min of He. Oven temperature was programmed to increase from 100 °C to 200°C at 10 °C/min, injector and detector temperatures were 240 °C. Volatile fatty acids were identified by comparison of their retention times with standard of water soluble fatty acids mixes (Cat.# 47056, Supelco, Bellefonte, PA-USA).

2-4 Growth trial

Twenty-four male Najdi lambs were divided into 4 groups of 6 animals each. The offered diets (QT0, QT1, QT2 and QT3). Lambs were fed indoors in individual pens for 120 days. All animals were provided with drinking water *ad libitum* and had access to lick mineral blocks freely. Animals were weighed at the start and at biweekly intervals throughout the growth trial. Feed and water were removed from each animal 15 h before weighing. Feed offered and feed residues were weighed daily along the growth trial to calculate the net intake of feed. Samples of diets were collected once weekly for the determination of DM intake. Average daily gains and feed conversion ratios were calculated.

2-5 Proximate analysis

Proximate analysis of the tested diets was determined using the standard AOAC (1990) procedures to determine DM, OM and CP content. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to the method of Van Soest *et al.* (1991), sodium sulphite was added.

2-6 Statistical analyses

Data were subjected to analysis of variance (ANOVA) using the Statview/SAS Institute, Inc. (1999). Significant differences between individual means were identified using least significance difference (LSD) multiple range test.

2. RESULTS

Data on degradation kinetics parameters of DM, NDF, ADF and N of experimental diets are presented in Table 1. Rapidly degraded fraction (*a*) of DM was not affected either by low or moderate levels of QT treatment (i.e. QT1 or QT2). Meanwhile, this fraction significantly ($P < 0.05$) declined at QT3. Slowly degraded fraction (*b*) of DM was significantly ($P < 0.05$) depressed when alfalfa hay was treated with QT at the level of 3%, while other treatments were not significantly affected. Degradation rate (*c*) declined insignificantly ($P > 0.05$) in all treated hay compared with control. Time needed to start degradation (L_t) was significantly increased ($P < 0.05$) for QT3 in comparison with the control diet. The effective degradability (*ED*) was significantly decreased ($P < 0.05$) for QT2 and QT3 compared to QT0 (Table 1).

The inhibitory effect of QT at the level of 3% was observed for the *b* fraction, degradation rate (*c*) and *ED* of NDF, while the L_t was significantly increased ($P < 0.05$) at the same level. However, no significant effect was found for QT1 and QT2. The degradation parameters for ADF showed similar trend as for NDF and the *b* fraction was 36.5, 38.8, 38.9 and 29.2; c rate was 0.029, 0.028, 0.027 and 0.023; and ED value was 15.7, 16.1, 15.8 and 10.7 for QT0, QT1, QT2 and QT3 respectively (Table 1).

The negative effect of QT on degradation kinetics of N was obviously noted. The degradation constants (*a*, *b* and *c* fractions) were significantly ($P < 0.05$) lower in QT2 and QT3 compared with QT0, while alfalfa hay treated by 1% of QT had minor effect on degradation constants. The L_t was increased ($P < 0.05$) in QT3 compared with QT0 and QT1, while QT2 had an intermediate value. A significant ($P < 0.05$) reduction was noted in *ED* of N for QT2 (68.6) and QT3 (64.6), compared with control (76.1) or QT1 (73.6) (Table 1).

The concentrations of total VFAs (m*M*) after 24 h of *in vitro* incubation decreased nonsignificantly for QT1 and QT2, but it was significantly lower ($P < 0.05$) for QT3 compared with control. The proportions of acetate, propionate, *n*-butyrate and *iso*-butyrate were not affected by treatment compared with QT0. Lower proportions of *n*-valerate ($P < 0.05$) and iso-valerate ($P > 0.05$) were noted as a result of adding QT to hay. The ratio of acetate to propionate was decreased significantly ($P < 0.05$) for QT3 compared with QT0, but this decrease was not significant in the case of QT2 (Table 2).

Table 3 shows the results of initial and final body weights, average daily gain (ADG), relative total weight gain [total body weight gain (kg)/ initial body weight (kg) x 100] and feed conversion of lambs as affected by different levels of QT. Total body weight gain, ADG and relative weight gain were higher ($P < 0.05$) for QT2 compared with control, while QT1 and QT3 had intermediate values. Under similar ($P > 0.05$) amounts of feed intake, the feed conversion was not significantly different among the tested diets, however, the feed conversion for QT2 was improved by about 18% compared with QT0.

3. DISCUSSION

Long time to start ruminal degradation (L_t) of DM was increased to 132, 132 and 138% for QT1, QT2 and QT3, respectively, compared to QT0, while *a* fraction was decreased to 92, 86 and 78% compared with QT0 for QT1, QT2 and QT3, respectively. The reduction of the *a* fraction and the increment of L_t led to decrease the extent of degradation (*a*+*b*) and *ED* of DM for tannin-treated alfalfa hay. This reverse correlation between the *a* fraction and L_t is supported by the findings of Makkar *et al.* (1989), who reported that the negative effect of tannins is to decrease attachment of microbes to feed particles and the interaction between tannins and cell wall of bacteria or extra-cellular enzyme secretion. Addition of QT reduced the extent of degradation in a dose-dependent manner which is in close agreement with previous studies *in vitro* (Getachew *et al.* 2000, 2008) and *in sacco* (Hervas *et al.* 2003). Moreover, Khazaal *et al.* (1993) found a negative relationship between gas production (an indicator of ruminal degradation) and the concentrations of phenolics in assessing phenolics-related anti-nutritive factors in browse species.

Degradation parameters for NDF and ADF (*b*, *c*, L_t and *ED*) showed no adverse effect for QT at levels of 1% and 2%. The insignificant effect of QT on degradation of NFD and ADF could be due to degradation mechanism of fiber in the rumen. Bae et al. (1993) suggested that condensed tannins (CTs) are able to bind and inhibit activity of extracellular enzymes efficiently than those of cell-associated enzymes. Thus for example, hemicellulases have been reported to be more sensitive to the inhibitory effect of CTs compared to cellulases. The negative effect of QT for QT3 on *ED* of NDF and ADF, which were lower by 70.4 and 68.3% compared to the control, could be due to increased extent of the adverse effects of QT on preventing microbial adhesion onto food particles.

The inhibitory effect of QT was more prominent on N degradation parameters compared to DM. Forming hydrogen bonds between the phenolic sub-units of the polymer and the carbonyl groups the protein results in tannin-protein complexe which may protect protein from ruminal degradation (Barry & Manley 1984). The effect of CTs from *L. corniculatus* on 11 strains of rumen bacteria was studied by Min et al. (2005) who concluded that CTs reduce rate of proteolysis and inhibits growth of proteolytic rumen microorganism, and these effects were correlated to the level of CTs. Hervás et al. (2003) reported that the intra-ruminal administration of CTs at a level of 2.8% of DM had no effect on ruminal fermentation activity and crude protein degradation in alfalfa hay, while a dose of 8.3 % of DM negatively impacted these parameters. On the contrary, results of the current study suggested that QT at a level of 2% or 3% of DM (equivalent to 1.5 and 2.25 g of CTs/100 g DM) could be applied to reduce degradation rate and *ED* of N in alfalfa hay. This disagreement could be attributed to differences in the procedures used for mixing tannins with the alfalfa hay. Tannin-protein complexes might be increased as a result of using steam (Makkar & Singh 1992). Therefore, high temperature and steam during hay pelleting procedure used in the current study could increase the ability of binding tannin with alfalfa protein. Moreover, the lack of significant reduction of ruminal NH_3-N concentration (an indicator of N degradation) when CTs were intra-ruminally administered at 2.8 % of DM (Hervás et al. 2003) and *in virto* study at 2% of DM (Getachew et al. 2008) could be attributed to the lack of opportunity for formation of tannin-protein complex in the bolus through mastication before the soluble proteins are exposed to bacterial degradation (Mangan et al. 1976; Komolong et al. 2001).

The pattern of total VFA concentration as affected by different levels of QT was parallel to the results found in the current study for degradation kinetics of DM and fiber fractions. The negative correlation between QT level and VFA concentration could be attributed to the impeding effect of QT on the activities of rumen microorganisms. This finding is in agreement with those of Liu *et al.* (2002) who reported that gas production is an indicator for the production of VFA, which is positively related to microbial activities. Results of the current study are in agreement with extensive reports on the suppressive effects of CTs on rumen degradation, and on the interference of these compounds with microbial attachment to feeds (McLeod, 1974; McAllister *et al.*, 1994; Aharoni *et al.*, 1998; Getachew *et al.*, 2000; Rubanza *et al.*, 2005).

Acetic acid concentration (TVFA x acetate proportion) was higher by 14% in QT1 than QT3, also the acetate: propionate ratio was significantly lower in QT3 than QT1. These differences reflect a trend of lower ruminal digestion of NDF and ADF of QT3, and could be due to the low availability of fermentable carbohydrates in the rumen. The higher acetate: propionate ratio in the QT0 coincides with the higher amount of NDF degraded in the rumen, since fiber degradation is related to the increase in acetic acid production. Evitayani *et al.* (2004) reported that the CTs not bound to protein can inhibit fermentation of structural carbohydrates in the rumen by forming indigestible complex with cell wall carbohydrates, rendering them undegradable, and inhibiting cellulase (Makker, 1995). Total branched short chain fatty acids (TBSCFA; *iso*-butyrate, *n*-valerate and *iso*-valerate) were decreased due to QT addition. Moreover, the proportion of *n*-valerate was significantly lower ($P < 0.05$) for QT1, QT2 and QT3 compared to control. Demjanec et al. (1995) found that the molar proportion of branched-chain fatty acids (valerate, *iso*-butyrate and *iso*-valerate) were higher when sheep were fed unheated soybean meal and decreased in linear fashion with roasting time of soybean meal. These changes in the proportion of these TBSCFA were anticipated because branched-chain VFAs are produced by microbial deamination of branched chain amino acids. This finding is confirmed by the results of N degradation found in the current study for treated hay and QT0. Significant increases in *in vitro* VFAs and branched chain fatty acid production were also observed when polyethylene glycol was added for binding of tannins in the *in vitro* fermentation of tanniferous trees like *Calliandra calothyrsus*, *Leucaena diversifolia*, *L. pallida* (McSweeney et al., 1999) and *A. angustissima* (Hoffmann et al., 2000).

Metabolizable protein is the sum of ruminally undegraded protein escaped rumen degradation and microbial nitrogen synthesis in the rumen that passes to the post-ruminal tract and this would be available for intestinal digestion and support animal needs from amino acids. In the current study the ruminally undegraded protein (100-*ED*) or [100 – (a+b)] was significantly increased by about 31% in QT2 than QT0. Moreover, supplying alfalfa hay with QT at the level of 2% significantly increased the synchronization between energy and N released in the rumen, which would lead to increased microbial N synthesis

(Kamel and Al-Dobaib, 2007). These findings might explain the enhancement of total body weight gain in QT2 than control, as a result of greater availability of N and amino acids for absorption in the small intestine. In agreement with our results, Mangan (1988) and Reed (1995) reported that the active CTs in a diet tend to increase the amount of abomasal non-amonia nitrogen (NAN) flow relative to N intake, and Waghorn et al. (1994) concluded that feeding legume species containing moderate levels of CTs were associated with a greater N or amino acids in small intestine. Also, Ben Salem et al. (2005) reported that acacia tannins reduced proteolysis; therefore absorbable protein reaching the small intestine would be more than with the acacia-free diet.

Enhancement of feed conversion found in QT2 (about 18 % more than QT0) could be attributed to the effect of CTs on protecting N from excessive ruminal degradation and promoting the efficiency of microbial N synthesis without affecting intake. The positive response of ADG and feed conversion ratio at the 2% QT gives an indication that the binding effect of tannins was pronounced at the level and supplying higher amounts of N that were subsequently used for tissue growth. Hence, the 2% QT is apparently the optimum level at which there is enough tannins to exert positive effects, while higher levels of tannins (i.e. > 2% QT) would have negative impacts.

4. CONCLUSION

Addition of QT to alfalfa hay reduced the *in vitro* rumen degradability of DM and N in a dose-dependent manner. The inhibitory effect of QT was obviously noted on degradation parameters of N at levels 2 and 3% of QT (equivalent to 1.5 and 2.25 g CT/100 g DM). Reduction of rumen degradability of N in QT2 is beneficial for lambs as it would increase the supply of N to the post-ruminal tract and subsequently increasing gain of lambs. In addition, these effects lead to protein-sparing effects in ruminants and reducing urinary N excretion to the environment, thereby reducing environmental pollution.

Table 1. Effect of different levels of quebracho tannin (QT) supplemented to alfalfa hay on *in vitro* degradation parameters of dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF) and nitrogen (N).

	Levels of QT†				
	QT0	QT1	QT2	QT3	SEM
DM					
a	27.3^{a}	25.2^{ab}	23.4^{ab}	21.4^{b}	0.78
b	63.4^{a}	63.1^{a}	61.5^{a}	57.2^{b}	0.94
c	0.062	0.060	0.055	0.051	0.002
L_t‡	1.6^{b}	2.1^{ab}	2.1^{ab}	2.2^{a}	0.10
ED§	68.0^{a}	64.7^{ab}	60.7^{bc}	55.1^{c}	1.95
NDF					
b	46.8^{a}	47.9^{a}	49.3^{a}	38.5^{b}	1.04
c	0.041^{a}	0.039^{a}	0.039^{a}	0.032^{b}	0.002
L_t	3.42^{b}	3.83^{ab}	3.91^{ab}	4.73^{a}	0.32
ED	24.4^{ab}	24.1^{a}	24.8^{a}	17.2^{b}	1.85
ADF					
b	36.5^{a}	38.8^{a}	38.9^{a}	29.2^{b}	0.56
c	0.029	0.028	0.027	0.023	0.003
L_t	4.3	4.6	5.2	5.6	0.45
ED	15.7^{ab}	16.1^{a}	15.8^{a}	10.7^{b}	1.32
N					
a	29.9^{a}	29.1^{a}	26.6^{b}	25.6^{b}	0.42
b	65.9^{a}	64.5^{a}	57.7^{b}	54.7^{b}	1.29
c	0.091^{a}	0.093^{a}	0.082^{b}	0.076^{b}	0.002
L_t	0.8^{b}	0.7^{b}	1.0^{ab}	1.4^{a}	0.13
ED	76.1^{a}	73.6^{a}	68.6^{b}	64.6^{b}	1.09

†Alfalfa hay + 0% of QT (QT0), alfalfa hay + 1.0 % of QT (QT1), alfalfa hay + 2.0 % of QT (QT2) and alfalfa hay + 3.0% of QT (QT3).

a (%), b (%), and *c(% per h)* are constants predicted by the exponential equation $P = a+b\ (1-exp^{-c(t-Lt)})$ as proposed by McDonald (1981).

‡L_t= lag time (h), calculated as reported by McDonald (1981).

§ED (%) = *in vitro* effective degradability calculated as: $ED = a + [b \times e^{-kxLt} \times c/(c+k)]$, where *k* is fractional outflow rate of solid particles from the rumen, assumed to be 0.03 per hour.

[a,b,c] Means in the same row with different letters in their superscripts differ significantly ($P < 0.05$).

Table 2. Effect of different levels of quebracho tannin (QT) supplemented to alfalfa hay on total volatile fatty acids (VFAs, m*M*), molar proportions of individual VFAs, *in vitro*

	Levels of QT†				SEM
	QT-0	QT-1	QT-2	QT-3	
Total VFA (m*M*)	45.8[a]	43.2[ab]	43.3[ab]	40.9[b]	1.05
VFA proportions					
Acetate	0.662	0.680	0.657	0.652	0.035
Propionate	0.170	0.168	0.187	0.189	0.015
n-Butyrate	0.091	0.094	0.096	0.098	0.008
iso-Butyrate	0.017	0.017	0.017	0.018	0.001
n-Valerate	0.04[a]	0.028[b]	0.029[b]	0.029[b]	0.002
iso-valerate	0.020	0.013	0.014	0.014	0.002
Acetate:propionate	3.90[a]	4.05[a]	3.51[ab]	3.44[b]	0.100

†Alfalfa hay + 0% of QT (QT0), alfalfa hay + 1.0 % of QT (QT1), alfalfa hay + 2.0 % of QT (QT2) and alfalfa hay + 3.0% of QT (QT3).
[a,b] Means in the same row with different letters in their superscripts differ significantly ($P < 0.05$).

Table 3. Effect of different levels of quebracho tannins (QT) supplemented to alfalfa hay on growth performance of lambs

	Levels of QT†				
	QT0	QT1	QT2	QT3	SEM
Initial body weight (kg)	28.3	29.0	29.9	29.9	1.46
Final body weight (kg)	45.5	48.2	50.3	48.0	2.04
Total body weight gain (kg/ 120 days)	17.2[b]	19.2[ab]	20.4[a]	18.1[ab]	0.72
Average daily gain (g/day)	143	160	170	151	7.75
Relative total weight gain (%)‡	60.7[b]	66.2[ab]	68.2[a]	60.5[b]	1.85
Total feed intake (kg/ 120 days)	165	164	161	153	2.95
Feed conversion	9.59	8.54	7.89	8.45	0.46

†Alfalfa hay + 0% of QT (QT0), alfalfa hay + 1.0 % of QT (QT1), alfalfa hay + 2.0 % of QT (QT2) and alfalfa hay + 3.0% of QT (QT3).
‡ Relative total weight gain (%) = Total body weight gain (kg)/ initial body weight (kg).
[a,b] Means in the same row with different letters in their superscripts differ significant ($P < 0.05$).

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الملخص العربى

تأثير إضافة مستويات مختلفة من تانين الكيوبراتشو على ميكانيكية التحلل و كفاءة نمو الحملان

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أجريت هذه الدراسة لتقييم إضافة مستويات مختلفة من تانين الكيوبراتشو إلى دريس البرسيم الحجازي (ألفالفا) وتأثيره على ميكانيكية تحلل كل من المادة الجافة- مكونات الألياف- النيتروجين و التركيز الكلى و المنفرد للأحماض الدهنية الطيارة- معملياً. كذلك تمت دراسة كفاءة نمو حملان النجدي و تأثرها بإضافة تانين الكيوبراتشو باستخدام عدد ٢٤ حمل. تم معاملة دريس البرسيم بتانين الكيوبراتشو بالمستويات صفر ، ١ ، ٢ ، ٣٪ من المادة الجافة. الجزء سريع التحلل في الكرش من المادة الجافة لم يتأثر بالمستويات ١٪ و٢٪ من التانين بينما حدث إنخفاض معنوي لهذا الجزء عند معاملة دريس البرسيم بالتانين عند مستوي ٣٪. الجزء البطيء التحلل في الكرش للمادة الجافة عند مستوى ٣٪ إنخفض معنوياً عن غير المعامل بالتانين- بينما لم يوجد تأثير معنوي للمعاملة ١٪ و ٢٪. معدل تحلل المادة الجافة في الكرش تناقص بصورة غير معنوية في كل المعاملات مقارنة مع الكنترول. الزمن اللازم لبدء تحلل المادة الجافة في الكرش إرتفع معنوياً للمادة الجافة في دريس الألفالفا المعامل بـ ٣٪ من تانين الكيوبراتشو مقارنة مع الكنترول. لوحظ التأثير المثبط المعنوي لتانين الكيوبراتشو عند المستوى ٣٪ على تحلل الجزء بطئ التحلل و معدل التحلل و كفاءة التحلل للألياف المقاومة للتحلل في المحاليل المتعادلة- كما وجد ان الزمن اللازم لبدء التحلل قد زاد معنوياً مقارنة بالكنترول. قياسات تحلل الألياف المقاومة للتحلل في المحاليل الحامضية كانت مشابهة لقياسات الألياف المقاومة للتحلل في المحاليل المتعادلة- وكانت قيم الجزء بطئ التحلل ومعدل التحلل وكفاءة التحلل هي ٣٦,٥ و٣٨,٨ و٣٨,٩ و ٢٩,٢٪ ، ٠,٠٢٩ و٠,٠٢٨ و٠,٠٢٧ و٠,٠٢٣ (٪/ ساعة) ، ١٥,٧ و ١٦,١ و١٥,٨ و١٠,٧٪ وذلك لدريس الألفالفا + صفر ٪ تانين ودريس الألفالفا + ١٪ تانين ودريس الألفالفا + ٢٪ تانين ودريس الألفالفا + ٣٪ تانين الكيوبراتشو على التوالي. ثوابت التحلل للنيتروجين (الجزء سريع التحلل ، الجزء بطئ التحلل ، معدل التحلل) إنخفضت معنوياً عند إضافة التانين بمعدل ٢٪ و ٣٪ من المادة الجافة لدريس الألفالفا مقارنة مع الكنترول- بينما معاملة دريس الألفالفا بإضافة تانين الكيوبراتشو بمستوى ١٪ كان له تأثير محدود علي القياسات السابقة.

التركيز الكلي للأحماض الدهنية الطيارة بعد ٢٤ ساعة من التحضين المعملي إنخفض معنوياً عند المستوي ٣٪ من التانين مقارنة بالكنترول. نسبة حامض الخليك تناقصت عند إضافة التانين إلى الدريس. نسبة البروبيونك والبيوترك وايزو-بيوترك لم تتأثر بالمعاملات مقارنة مع الكونترول. النسبة بين حامض الخليك إلي البروبيونك إنخفضت معنوياً عند إضافة التانين بمستوي ٣٪ بينما لا يوجد فروق معنوية عند المستوي ١ و٢٪ مقارنة مع الكنترول.

الزيادة الكلية في وزن الجسم ومعدل الزيادة اليومية والزيادة النسبية في وزن الجسم إزدادت معنويا عند إضافة التانين بنسبة ٢٪ لدريس الألفالفا مقارنة مع الكنترول - بينما إضافة التانين عند مستوي ١ و٣٪ لدريس الألفالفا أعطي قيم وسطية بين الكنترول والمستوي ٢٪. معدل التحويل الغذائي لم يختلف معنوياً عند إضافة التانين ولكنة تحسن بمقدار ١٨٪ عند إضافة التانين بمستوي ٢% مقارنة مع الكنترول.

إضافة التانين إلي دريس ألفالفا قلل من تحلل المادة الجافة والنيتروجين (معملياً) تبعاً لمستوي الإضافة. إنخفاض تحلل النيتروجين عند إضافة التانين بمستوي ٢٪ مفيد للحملان حيث أنه زاد إمداد النيتروجين إلى ما بعد الكرش وبالتالي أدي إلى زيادة النمو في الحملان.

الكلمات المفتاحية: كيوبراتشو تانين، دريس البرسيم الحجازي ، ميكانيكية التحلل، الأحماض الدهنية الطيارة، النمو.